MYSORE • GEOLOGICAL DEPARTMENT.

BULLETIN

NO. I.

MINE SIGNALLING.

BY

W. F. SMEETH, M.A., D.SC., &C.,

State Geologist and Chief Inspector of Mines.

BANGALORE:

PRINTED BY HIGGINBOTHAM & Co.

1904.

Price—~~One Rupee~~. 2/3

MINE SIGNALLING.

BY W. F. SMEETH.

I.—Electric Signalling.

In my Report on the Inspection of Mines in Mysore for the year 1899, I drew attention to the fact that numerous serious accidents had occurred, and were likely to occur again, which were largely due to defective methods of signalling in shafts. These defects were, I pointed out, inherent in the "knocker-line" system of transmitting signals usually adopted.

The knocker-line consists of a wire stretched from top to bottom of the shaft and connected at the top to a hammer which strikes a bell or some iron plates. At each level in the shaft a lever is attached to the line by means of which it can be moved, thereby causing the hammer to strike the bell at surface. A number of strokes of the bell constitutes a signal of definite import according to a pre-arranged code and the level from which the signal is given can be indicated by a number of strokes equal to the number of the level—one for the first level, two for the second level and so on. Apart from this conventional signal, there is no means by which the lander at surface can tell from which level in the shaft any signal is given and any person can give any signal from any one of a dozen or more levels in a big shaft. This constitutes one of the grave defects of the system and has been a fruitful source of accident. For instance, when the skip or cage is resting at a certain level and men are working at it or entering it, some one, who wants the skip at another level, may signal for the cage to be raised or lowered and if the signal is complied with, somebody at the first level is

liable to be injured. Accidents of this kind have frequently occurred in spite of rules which provide for signals to indicate the various levels and for special signals designed to keep an engaged skip stationary. The very cumbersomeness of these signals militates against their general adoption and against a strict adherence to them and if, in defiance of rules, a person has given a prohibited signal from some level other than that at which the skip is halted and an accident results, that person is never to be found.

Another serious defect, though less so than the former, of the knocker line is its unsuitability for the transmission of return signals from surface to the levels below. Such return signals would not only tend towards greater safety in working, especially in the raising and lowering of persons, but would in other ways prove of great convenience.

With these defects in view, to say nothing of the mechanical difficulties of the system, I suggested to the Kolar Gold Field Mining Board that some general improvement in the methods of signalling might be considered and that preferably electrical methods might be introduced in place of mechanical ones. The Mining Board considered the question in detail with the advice of their Electrical Engineers and decided to adopt an Electrical system by which,

(*a*) signals could be received and identified from each level,

(*b*) it should be impossible for unauthorised signals to be given from any level without the knowledge of the lander at the surface,

and (*c*) the lander should be able to transmit return signals to each level independently.

There was considerable difference of opinion as to whether the return signals mentioned in clause (*c*) should be insisted upon in all cases and the decision finally arrived at was that,—

> in all shafts in which men are carried return signals to each level should be provided, and that,
>
> in shafts in which men are not carried return signals, though recommended, need not necessarily be provided, the conditions laid down in clauses (*a*) and (*b*) being deemed sufficient in such cases.

Under these conditions the systems now being adopted and which I am about to describe were worked out by Mr. Harold Hincks, Assoc. M. Inst., C. E., Acting Chief Engineer of the Kolar Gold Field Electricity Department, to whom I am indebted for the accompanying diagrams (Plate I, Figs. 1, 2, 3) and for some notes upon which the following description is based :—

A.—SIMPLE SYSTEM FOR SHAFTS CARRYING STUFF ONLY.

The diagram Fig. 1 shows the general arrangement and system of wiring. At the shaft top is the Battery from which one wire (x) passes to the Bell and thence to the upper terminals of the Indicator. The other wire (y) is led continuously down the shaft. At each levels the wire (y) is connected by a short lead (z_1, z_2, z_3) with the lever of a simple key and the circuit continued thence by a wire (a, b, c, &c.) passing up from the level to the lower terminal of the Indicator.

Signals from any level—say the 1st—are given by pressing the key at that level which completes the circuit through *x*, *y*, and *a*, thereby ringing the bell and causing the Indicator shutter (1) to drop. Each time the key is pressed the bell rings and the number of rings forms the signal according to a prescribed code. When the signal is given from the 1st level the Indicator shutter (1) drops and when given from the 2nd level the shutter (2) drops and so on, so that in each case the lander sees clearly from which level the signals are being given. As the lander knows at which level in the shaft the skip is halted, he will pay no attention to signals from any of the other levels and until he receives a signal from the level at which the skip is, he will not signal the Engine Driver to move the skip. (I should mention that on the Kolar Gold Field signals from below are always received by the lander at the shaft top and transmitted by him to the Engine Room, no signals being sent direct to the Engine Driver from below). It will be seen that by this simple system conditions (*a*) and (*b*) required by the Mining Board are fulfilled and that the main defect of the Knocker-line which I have referred to above is obviated.

B.—SYSTEM PROVIDING FOR RETURN SIGNALS.

This is illustrated by the diagram Fig. 2 and comprises the former simple system for the signals from below to surface together with a separate battery for working the bells at each level from surface. It will be seen that the return signals require only a single additional wire to be put down the shaft, *viz*, the wire *z*. The signals from below are given precisely as in the simple system, the

Indicator showing from which level the signal comes To return the signal to the same level the lander has only to depress the Morse-key on the Indicator circuit of that level. For instance a signal from the 2nd level will lower the Indicator shutter " 2". To return this signal the lander depresses the Morse-key below "2" which breaks the "direct" circuit and completes the "return" circuit through the return battery and the wires w, b, k_2, z, thereby ringing the bell at the 2nd level. Thus signals can be sent from each level to the lander who is informed by the Indicator from which level the signals come and the lander can independently send down any signal to any level which he wishes to communicate with.

The system is, I think, a very good one and is probably as simple as can be devised for effecting the interchanges above mentioned.

C.—SIGNALS FROM THE SHAFT TOP TO THE ENGINE ROOM

On the Kolar Gold Field no signals are permitted to be sent from below direct to the Engine Room. All signals are received by the lander at the shaft top and instructions for moving the cage or skip transmitted by him to the Engine Room. For transmitting these instructions the following two systems of signalling are in use:—

1. For ordinary cases in which the cage or skip is worked from various levels in a shaft a system similar to the simple system (Fig 1) is employed, the Indicator board and the bell being in the Engine Room and the keys

being arranged in a row at the shaft top. The following signals are usually employed :—

One ring ...	...	Stop.
Two rings ...	...	Lower.
Three rings...	...	Hoist.
Four rings ...	...	Lower slowly.
Five rings ...	...	Hoist slowly.

The push on which a signal is given represents the level to which the cage is to be moved. Thus 2 rings on the 5th push causes the Indicator 5 in the Engine Room to drop and the driver knows that he is to lower the cage to the 5th level. If there are two cages, when one is at any level the other will be between levels and the signal applies only to the cage which is *at* a level.

2. In some cases the cage may be required to stop only at one level below ground—say at the bottom of a vertical shaft—and the Indicator in the Engine Room, representing the various levels, will not then be necessary. In such cases the Indicator may still be retained and used to *show* the Engine Driver the signals from the shaft top in addition to the audible signal given by a number of strokes of the bell. This arrangement is represented in Fig. 3. The signal "one—to stop" is always given on the first push and lowers the shutter "1" of the Indicator. The signal "two" is always given on the second push and lowers the shutter "2" and so on. The Engine Driver has thus an opportunity of both hearing and seeing the signal sent to him and the arrangement is said to be useful in noisy situations.

In these arrangements the bells which have been provided are "single stroke" and it is very doubtful

whether a signal composed of single strokes will prove reliable in a noisy Engine Room as the driver may fail to hear some of the strokes and may misunderstand the signal. This danger is obviated by the 2nd arrangement above described, but this latter has only a limited applicability and I think it will probably be found advisable to use a trembling bell in the Engine Room instead of a single stroke bell. On one mine (Ooregum) the bell in the Engine Room is used merely as an alarm to attract attention and the signals are given by the lander to the driver through a speaking tube and this may be found to work satisfactorily. I would suggest also that a combination of the systems (1) and (2) already described might be found advantageous for general work, especially if a trembling bell is used. System (2) would be used for the signals to stop, raise, or lower, each signal being given on its special push after which the same signal on any push would denote the level corresponding to that push or *vice versa*. Thus 4 bells on the 4th push would mean lower slowly and then 4 bells (the same signal repeated) on the 7th push would mean "to the 7th level."

The driver could thus both hear and see the signal for stopping or running the cage as well as that indicating the required level. The reason why I suggest repeating the moving signal on the push which indicates the level instead of simply one ring on that push is to avoid any confusion with the signal "one—to stop" given on the 1st push. If one ring was always used to denote a level then "one" on the first push would mean also 1st level, whereas it should be reserved solely for the signal "to stop" and should be capable of being given at any moment and as a countermanding signal to any other.

D.—APPARATUS.

Taken as a whole the systems of signalling described above appear to me to afford very complete and effective means of communication in shafts and in particular to provide those safeguards which I have previously referred to as being very necessary.

I may now add a few words about the apparatus which is being put into the shafts of the Kolar Gold Field for working these signals.

Sufficient apparatus for 40 shafts with an average of 10 levels per shaft has been provided and already 15 of the principal shafts have been fitted with the return signalling system.

The conducting wire consists of 70 miles of 3/22 S. W. G. tinned hard drawn copper wire, insulated to No. 9 S. W. G. with vulcanised rubber, taped, braided and compounded and then armoured overall with strong galvanized iron wire. The complete wire is capable of sustaining its own weight without injury for a length of 2,000 feet. All bells, indicators and pushes or keys are enclosed in strong iron cases which have been specially made and are, as far as possible, water and gas proof.

All the bells which have been provided are single stroke bells.

Each battery consists of 8 No. 1 Leclanche cells fitted in strong teakwood boxes with wooden partitions.

The wires taken down the shaft are passed through holes in wooden blocks which are fixed on every second

"set." The long wires shown in the diagrams as running continuously down the shaft are, in practice, taken in to each level for some distance and there bent back and carried out again and down to the next level. At the bend inside the level the insulation is removed and connection made to the key or bell and the junctions reinsulated.

It may be noted that in some previous electrical work in some of the shafts, lead covered wires were employed and it was found that in comparatively few months the lead covering was corroded and the insulation damaged or destroyed; hence the adoption of the complex wire mentioned above.

So far as I am able to judge, all the apparatus which is being put in for the purpose of these signals is of first class material and workmanship and is correspondingly costly. Such initial cost is of course likely to save expense in the long run and provided that the system adopted works with few breaks-down and with a small bill for renewals and repairs the total expenditure incurred can hardly be of any moment compared with the cost of sinking and maintaining the shaft itself. To equip a mine which has several working shafts with electrical signalling apparatus of the best design and workmanship, will probably cost several hundreds of pounds and if the mine is not in a flourishing condition the provision of such a sum for this purpose may be objected to. To meet such cases certain proposals which I shall make below for modifying the knocker line system may be found worthy of consideration.

E.—OTHER SYSTEMS.

I now pass on to a few more remarks about electrical signals.

In Fig. 4 (Plate 1) is shown a scheme which I have devised for return signalling which is somewhat simpler than that shown in Fig. 2, but without some of the advantages of the latter.

The numbering and arrangement of the wires are the same as in the " Simple system " (Fig. 1). In addition a single stroke bell is placed on the circuit to each level and each circuit can be broken at surface by a key or push beneath the indicator. If the surface bell is single stroke it may be placed on the main circuit. The signals are given in the following way :—When the key at any level is depressed the bell at that level and the surface bell each give one stroke and the indicator for that level falls just as in Fig. 1. The man at the level hears on his own bell the signals sent to surface and knows that the circuit is working. To obtain a return signal he holds the key down at the last stroke of the signal which he has given and the lander at surface by depressing the key beneath the indicator breaks the circuit. Each time the lander depresses and releases this key the circuit is broken and made again and the bell at surface as well as the bell at the level each ring one. The signal is thus returned to the level from which the call came after which the man at the level releases his key.

If it is desirable to have a trembling bell at surface so as to better attract the lander's attention, it will be necessary to put this bell on a branch circuit as shown in

Fig. 4 or better still to have it worked by a relay. The scheme has the disadvantage that it does not permit of the lander giving a signal to any level except in reply to a signal from that level and is consequently much less complete than the somewhat more complex system shown in Fig. 2.

Fig. 5 shows a system which was in use on one of the mines on the Kolar Field, but which cannot be recommended owing to certain defects to which it may be useful to call attention.

A signal from below—say the 1st level—is given by connecting a to the battery at the level when the current passes through a—x—the surface bell—and the first indicator. The return signal is given by depressing the Morse-key beneath the indicator, thus connecting the surface battery with the circuit a, y, x, k_1 on which the bell at the first level is placed.

The disadvantages of this system are—firstly,

the necessity for having a battery at each level which not only involves the use of a large number of cells, but also the placing of these cells below ground, which in many mines is undesirable for efficiency and good work; and—secondly,

the fact that the circuits are not independent so that more than one bell is rung when a key is depressed. For instance, if the key at the first level is depressed, not only does the current pass through x and a, but some goes down through k_2, and b, thereby ringing the bell at the 2nd level and dropping the 2nd indicator and so on down the levels until it is too weak to produce a signal. Similarly when the Morse-key below the first indicator is depressed in

order to send a signal to the 1st level the current passe not only through *a*, k_1, *x*, *y*, but a current also goes dow *x* below the first level, through k_2, *b*, indicator (2) an the surface bell as well as branch currents through th other indicators and bells. The system was, I believe made to work by removing the surface bell and puttin in a high resistance bell just above each indicator whic arrangement would tend to diminish the evil effect without of course removing the defects of the system.

An ingenious scheme in connection with electri signals has been suggested to me by Mr. J. D. Cosen Chief Engineer of the Tank Mine, and is diagrammaticall represented in Fig. 6. The idea is to introduce a arrangement in connection with electric signals whic will permit of a signal being sent up from the level a which the cage is situated, or from any level when th cage is within any given distance above or below th level, and at the same time prevent signals from bein sent from any other level in the shaft. The arrangemen proposed is to have a screw spindle (S. Fig. 6) couple direct to the gudgeon of the pit head pulley. Travellin on this screw is a nut which is electrically connecte with the surface bell by a sliding contact or otherwise The nut also makes contacts with a series of copper bar *a*, *b*, *c*, &c., and is at the middle of each bar when th cage is at the 1st, 2nd, 3rd, &c., level The length of the bars *a*, *b*, *c*, determines how far above or below any level the cage can travel without electrical communication with that level being interrupted. Fig 6 shows a return signalling system with the above arrangement added. When the cage is at the 1st level *k* is in contact with *a* and the surface bell can be rung from the first level and from no other level. Indicators though shown in the

sketch are not necessary as the lander knows at which level the cage is halted and he also knows that any signal received must come from that level. If two cages are in use there must be a screw and series of contacts for each of the pit head pulleys, so that a signal may be sent independently from whichever level either cage may be at. In order that the lander may be able to distinguish to which cage any signal refers there should be either two surface bells or an indicator should be provided for each level as shown in the sketch.

I mention this scheme as it is mechanically interesting and might lead to other developments, but I doubt if it is likely to be introduced in the case of shafts provided with a complete set of return signals, such as that shown in Fig. 2, for the sake of preventing signals from being sent from any level unless the cage is near that level. It might be found useful for a shaft provided with simple (not return) signals and not provided with indicators.

II—Some modifications of the Knocker-line.

When I suggested some two years ago that electrical signalling should be introduced in the mines of the Kolar Gold Field in place of the knocker-line commonly in use, I did so because of the obvious disadvantages of the latter and because of the ease by which these disadvantages could be overcome by the adoption of electrical methods.

The introduction of the electrical methods has taken a long time and is yet far from complete and as I have already pointed out a good installation costs a great deal of money. Some time ago it occured to me to enquire whether it would not be possible to remove the essential disadvantages of the knocker-line by some simple and inexpensive modifications and I have worked out certain schemes which I think are worthwhile trying and which I mean to test experimentally. On papers these schemes appear to be all right, but there are certain mechanical conditions which require to be satisfied if the schemes are to prove satisfactory.

The first problem was to remove the most serious defect of the ordinary knocker-line, *viz.*, the fact that a signal can be given from any level in the shaft, whether the cage is there or not, without the lander knowing where the signal comes from, the result being that the cage may be moved although the men who are with it require it to be kept stationary. With an electrical system it is possible and easy to make the signal itself indicate the level from which it is given, but with the knocker-line this is neither easy nor convenient to arrange. It is however quite easy to prevent a signal from being

given from any level except that at which the cage is engaged in the following manner:—

In place of the usual hammer which is worked up and down by the knocker-line and which strikes a bell or some iron plates, the end of the line at the shaft top is connected with a lever *a* (see Fig. 1, Plate II) with a counter-balancing weight W, or a spring, at its end and kept from moving too far in one direction by a stop *s*. When the line is pulled *a* depresses a smaller lever *b* which raises the hammer *h* until *a* disengages from *b* (Fig. 3) when the hammer falls on to the bell. As the line is released *a* trips up *b* (Fig. 2) and passes it, *b* being pulled back into its original position by a spring attached to *k* which is rigidly connected with *b*. Each time therefore that the lever (l_1, l_2 . .) at any level is depressed the bell is struck.

Suppose now that the cage or skip is coming down to the 2nd level and is required by the men there to remain stationary for some time. The signal man by means of the lever l_2 gives any signal necessary to adjust the cage finishing with "one ring—to stop" and then instead of releasing the lever he fixes it down to a hook or other catch as shown in Fig. 3. The lever *a* is now altogether below *b* and it is obvious that no one in the shaft can give any signal except the man at the 2nd level. The cage can therefore be kept at that level so long as it is wanted after which the lever must be released and the cage rung away.

There is one further advantage in this arrangement which is that the lander can see when the lever has been put into safety positions and if after the cage has been

halted at some level the lever is not put to safety the lander can call a witness to see that such is the case and if subsequently an accident occurs owing to a signal being given from some level other than that at which the cage is halted the blame can be definitely fixed upon the man who failed to fix down the lever at the level where the cage was engaged.

Such an arrangement is simple, inexpensive and presents no mechanical difficulty and provides for all that is usually effected by the ordinary knoker-line.

It is however possible to go much further than this. In the first place return signals might be arranged for by making the line much lighter than usual and counter-balancing at each level. The lever at each level might be arranged as in Fig. 4 with a fulcrum at F. and a weight W_1 to balance the weight of the line between that level and the next and the lander could, by pulling down his lever sufficiently, move the lever l_1 until the end a, engages with the trigger of a bell B_1. The lander might even be able to ring B_1 when l_1 was fixed down in the safety position, for which it would only be necessary that the safety catch, instead of being a hook as shown in Fig. 3, should be a catch preventing l_1 from being raised but permitting it to be lowered or the other end of it raised until a_1 engages the bell trigger. Of course whenever B_1 was struck a similar bell would be struck at every other level and also the end of the surface lever would strike a bell B' for the lander's benefit. Thus whether the lever at any level was held down by the safety catch or not the lander could receive a signal from any level on B' and could return a signal which would be heard at that level; on the other hand the lander could

ring any interrogating or alarm signal down to all the levels in the shaft. All signals for moving the cage would still have to be rung on the main bell B so that the immobility of the cage at any level where it is engaged can still be secured by putting the lever at that level under the safety catch.

I have considered this point at some length, not because I intend to recommend the arrangement described for return signals, but just to show what might be possible with a simple line working bells by means of triggers. Mechanically the arrangement of a lot of counterbalancing weights actuated by a single line does not commend itself to me; it would require constant adjustment and in inclined shafts the sag of the rope would constitute a serious, if not prohibitive, defect. I therefore pass on to describe an arrangement which with materials of little weight and easily worked is far more rigid and capable of being easily kept in adjustment.

In this arrangement instead of one wire down the shaft there are two wires attached to the ends of levers situated at each level. At the surface (see Fig. 5) is a lever l pivoted at its middle and held up against a stop by a spiral spring (or balance weight). From the ends of l two light wires run down the shaft to a parallel lever l_1 at the first level and from this two more wires run down to a lever l_2 at the second level and so on down the shaft. Each wire can be tightened by a suitable straining screw so that all the wires are taut and all the levers parallel; the movements of any one level will then be followed very closely by all the other levers. By using light wires it will probably be found possible to stretch them sufficiently tightly from level to level to avoid any objectionable

sag, even in inclined shafts, as well as to do away with any rollers which not only cause friction but wear away the protective covering of the wires.

A bell B actuated through a trigger by the end of the lever l can be rung by moving any lever to the horizontal position and as before any lever can be kept down in the horizontal position by a stop s_1...thereby preventing a signal from being given from any other level (Fig. 6).

While any lever l_1 is in the horizontal position a signal can be sent to surface from any level by depressing the lever at that level far enough to ring a second bell B' and the lander can reply by depressing his lever still further to a third position which causes all the bells B_1, B_2, &c., at the various levels to ring, these bells being actuated by short levers m_1, m_2, &c., attached to the levers at each level. A guard may be placed near the lever at each level so that the signaller can only depress the lever sufficiently to ring the lander's bell B' but so that the lander can depress it still further and ring B_1, B_2, &c. and thus whenever one of these bells is rung the man below knows that it is a signal from surface.

The particular arrangements adopted in any given case will depend on the system of signals in vogue and on the purposes for which signals are required and I merely mention the above cases as illustrations of the sort of use to which the apparatus can be put. The success of the scheme, depends on the levers being kept in fairly parallel adjustment, but for such a simple scheme, involving only three important positions of the levers, a considerable amount of latitude or play is permissible. It appears to me however that with a moderate amount of attention the error of adjustment is capable of being kept within

such close limits that, within the arc through which it is practicable to move the lever, a considerable number of positions of any one lever can be faithfully recorded by all the others and assuming that such is the case I propose to show how further advantage may be taken of it.

Suppose that the levers can be conveniently moved through an arc of 90° and that Fig. 7 represents the arrangement when the cage is at the first level and l_1 has been caught underneath the stop s_1, that is to say, in the safety position. The lever l_1 is extended into an arm or pointer of convenient length which traverses an arc on which are a series of numbers representing the various levels as well as a series of instructions or signals, the whole arrangement forming an indicator which is identically repeated at each level and at surface.

The point being under the stop s_1 points to the signal " cage engaged " on all the indicators. When the cage is done with at the first level the man in charge releases s_1 and having raised the pointer to o rings the cage away on the signal bell B.

Again let us suppose the lever at a certain level held down under the safety catch s_1 and that it is required to change levels. The cage man attracts the attention of the lander by putting the pointer down to "enquiry bell" which causes a hammer on the surface lever to strike a simple alarm bell B′ at surface.

The lander may indicate attention by simply moving the lever slightly or more definitely by putting it down to " signal from surface" which causes a bell B_1 at the level to ring. The cage man then moves the pointer to " Take

out Clutch," then to "Move cage to," then to the number of the lever at which the cage is required; each signal may be repeated by the lander intimating that he has understood. Suppose for example the cage is at the 5th level and is required to be changed to the 4th level and that the above signals have been given and repeated; the lander knows exactly what is wanted but does not move the cage until the cage man at 5th level releases the safety catch and rings "3—to raise" on the signal bell. The cage is then raised and stopped at the 4th level and the man there having put the lever underneath the safety catch indicates "Put in clutch" which is repeated by the lander and work resumed.

Again, suppose that some one below wants the cage at the 7th level; he can ring up the lander on the "enquiry bell" and indicate "move cage to" and the level No. 7 when the lander will send down the cage if disengaged or after it becomes disengaged. In indicating the level numbers a single movement of the pointer along the arc indicates the level number at which it stops from 1 to 5. For the second row of numbers, say No. 7, the pointer is swept over the whole arc and back and moved the second time up to 7. Thus the numbers on the outer arc are indicated by the second motion of the pointer.

Again, if the cage has been stopped for some time at a level, the safety catch being down, the lander can ring the signal "signal from surface" and then indicate "cage wanted." If it is still required to remain at the level the signal-man just moves the pointer and lets it go back to "cage engaged;" if however the cage is free, the man below must release the safety catch and ring the cage away on the signal bell.

The scheme which I have here outlined purposes to provide :—

(*a*) a set of signals on a bell at surface for the purpose of moving or stopping the cage similar to those in use with the ordinary knocker-line ;

(*b*) a safety arrangement whereby no signal to move the cage can be given except from the level at which the cage is halted ;

(*c*) a number of dumb signals on a series of indicator boards enabling the cage man to give instructions to the lander and to receive replies ;

(*d*) a bell which can be rung from any level to call the attention of the lander ;

and (*e*) a series of bells, one at each level or where particularly required, all of which can be rung by the lander and by no one else (below) calling the attention of the cage man or signaller at the level where the cage is situated, also useful for the purpose of a general alarm signal.

The scheme is a very simple one and adaptable to various codes of signals in different mines. The mechanical difficulties do not appear to be great nor can the construction and maintenance be expensive—much less so than in the case of electrical signalling. The best form of apparatus and materials will naturally require some experimental work, but I think the scheme worth a trial and I hope to try it shortly. I might point out that if it

be found necessary in any case to increase the arc of th indicator to more than the 90° which I have suggeste an increase to 180° or even more could be obtained b substituting light wheels (perhaps of aluminium) for th levers l, l_1 l_2 &c., or, if found sufficient, by attaching arc of circles to the ends of these levers. Such matters ar merely questions of mechanical convenience.

MYSORE GEOLOGICAL DEPARTMENT.

BULLETIN

No. 2.

Air Blasts and Quakes

on the

KOLAR GOLD FIELD.

BY

W. F. SMEETH, M.A., D.SC., &c.,

State Geologist and Chief Inspector of Mines.

BANGALORE.

PRINTED BY HIGGINBOTHAM & Co.

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Price—One Rupee.

AIR BLASTS AND QUAKES.

BY W. F. SMEETH.

In my Report for the year 1899* I drew attention to the fact that "air-blasts," by which term is usually meant a splitting off of small portions of the reef quartz with a considerable amount of violence and noise, were frequent in the quartz of the Champion Lode, Kolar Gold Field, and often resulted in serious injuries to the workmen underground. Since then I have collected some information about these remarkable phenomena which I purpose to relate here; unfortunately my opportunities of experiencing these phenomena or of personally visiting the places where they have occurred have been few and the information available in many of the cases quoted is much less complete and precise than I would like it to be. The present notes must be regarded merely as a progress statement calling attention to certain salient features and suggestions with a view to securing more careful observation and eliciting further facts, confirmatory or otherwise, in future cases.

Previous to the year 1900 I had received many reports of air-blasts which did not appear to me to call for particular attention except in regard to their frequency. They did not seem to differ materially from the phenomena which are known to occur in Cornwall and which have been described by Prof. Le Neve Foster who imitated thêm by screwing up some sheet glass between the plates of a copying press thereby causing portions of the edges of the sheet to splinter and fly off. On the Kolar Gold

* Report of the Chief Inspector of Mines in Mysore.

crackling noise was audible most of the time and every now and then there was a report something like that produced by a squib or cracker and sometimes a sharper report approaching that produced by a small detonator. The quartz on a freshly broken face was of a translucent bluish grey colour which rapidly changed to white owing to production of numerous minute cracks, just as though the whole reef was beginning to give way under pressure. The production of these minute cracks caused the continuous crackling sound and every now and then a small grain would vanish with a little puff, apparently going to powder, or a small piece up to 2 or 3 ozs. in weight would fly out with a report. I watched this for some time and came to the conclusion that the effects noted must be due to the weight of hanging wall (the dip being about 55°) on the margins of the quartz. A considerable amount of ground had been stoped above the point referred to as may be seen from the diagram, Fig. 1. Consideration of a number of other cases however suggests that the superincumbent weight is not the sole cause of the effects noted, otherwise we should expect to get similar effects in many other places where the crushing weight is as great or greater; such a connection is however not borne out by experience as air-blasts occur frequently where there is no such obvious pressure and fail to occur where such pressure undoubtedly exists. Some further explanation must therefore be sought and in seeking for this I cannot do better than begin by quoting the remarks which Mr. P. Bosworth Smith, Superintendent of the Tank Mine, has kindly sent me in connection with an air-blast in the schist which he himself observed. These remarks are particularly valuable as they are made by a trained scientific observer, a condition often lacking in the reports obtainable during the

ordinary course of mining work. Mr. Bosworth Smi
says:—

Case 2.

"Regarding our conversation on "quakes" and "air-blasts," I have been fortunate enough to witness several of the latter and have seen such occurrence in "quartz," in "trap" and in the "country rock." These air-blasts in quartz and in trap are, I believe, common on the Field, but a blast in the schist away from the lode is uncommon and I have only seen one, nor have I heard of any others. I enclose a small tracing giving the locality of the occurrence. About 200 feet south of Walker's shaft in the 530 feet level we started a cross-cut east to open up our east lode. Visiting the end when the drive was about 60 feet in, I had just reached the machine bar wh
explosion took place on the face of
the end. The rock drill which had b
a minute before was stopped as I ca
the coolies working in it had been
from the drill in order that I co
straight to the working face. There
quently nothing to interfere with my
hearing the blast. The blast wa
ordinary detonator had been fixed on
the drive covered with a small heap
fired. The explosion sounded exa
and there was a small spit of fine
away from the end. There was
crackling of the rock giving warni
often occurs in the quartz and the
nor were there any subsequent smalle

The crack of the explosion was quite unexpected and very startling. The force of the explosion would probably have been sufficient to seriously injure the face and eyes of any person standing and examining closely the place where the explosion occured.

"These "air-blasts" have interested me for some time and several years ago I wrote to the Kolar Gold Field Mining Board giving my opinion that the cause of the phenomenon was similar to that of the explosion of a Prince-Rupert's drop or the bursting and crackling of a toughened glass globe. The glass in both these cases being very suddenly cooled, enormous internal strains are set up; these molecular strains are in equilibrium when the glass is whole and may be likened to a complicated system of threads all pulling violently on one point, but all neutralising one another; cut one of the threads and the whole system will suddenly collapse. In the case of a Rupert's drop the nipping of the thread of glass forming the tail upsets the balance of the internal strains and the whole mass flies apart with a loud report. Break a toughened glass globe and the pieces into which it is resolved will subdivide of themselves and will in many cases go on breaking themselves up for days afterwards, showing that in a solid these internal strains when not too violently thrown out of equilibrium take some time to assert themselves.

"The air-blasts that occur in the quartz may be caused by the pressure of the walls of the lode.

of our 530 cross-cut explosion. The end was very tight and was in fairly homogeneous hornblende schist breaking off to large head joints which dipped west with the ordinary banding of the rock. This carried a few small strings of calcite varying in width from 1/32nd to ½ inch and running parallel to the schistosity of the rock. These may have been introduced either by the whole rock being split up parallel to its schist lines and the calcite being carried into the fissures produced, or the little seams of calcite may have been crystallised out when the general metamorphism of the hornblende schist took place. Either cause might produce local strains: the former would be a small example of the fissure or lode pressure and seems unlikely, as if open fissures had been produced liable to be subsequently filled with new matter, the fissuring pressure would have been lost when the cracks formed. It also seems unlikely that the crystallisation of such strings of calcite could have caused sufficient strain to have made this blast. It seems more probable that during some of the great metamorphic changes which the hornblende schists have undergone, some chemical change took place by which the calcite strings were formed and that these changes introduced the local strain. My reason for supposing that the occurrence was in some way connected with the seams of calcite is that in many other places in Tank Mine where levels have been driven through rock seamed with calcite bands the rock is always "airing," as the miner calls it, *i.e.*,

cle
and
ass

tan

end of a cross-cut, far removed
west Lode and in a situation in
ıen no great pressure due to the
ɛft unsupported by reason of sur-
ıd the second is that the blast did
rock to be thrown out, but only
ıting that a small piece of rock in
·ed to fragments. With regard to
t the pressure due to depth was
a nature which can be regarded
he effect described, the same
be admitted in the case of several
ve been reported to me. For

ft (vertical), Ooregum, was being
a great deal of trouble was en-
ered about the level of the 1060 ft.
cut from Taylor's shaft, both in
ɔss-cut. Small air-blasts were of
his locality accompanied by sharp
ɪr projection of fairly large pieces
the hornblende schist is usually
ce or roof which on one day was
, the next day, be found much
Now the locality of these occur-
et west of the lode in solid back
texture and the only excavations
l the cross-cut entering it at right
m that in such a case the superin-
of itself produce the effects noted
t that these blasts did not occur
se either higher up or at lower
haft has subsequently been sunk.

shaft there seemed to be no room for the breaking off of any loose shales of rock such as may occur in obliquely bedded and shaly ground and I am inclined to believe that the cases I refer to were due to the genuine splitting off of fragments from the solid rock.

Case 6.

There is one more case to which I must refer and which takes us back from black rock to quartz.

In driving the 1940 ft. level, Champion Reef, air-blasts have recently been frequent causing the roof of the level to split and fly off in small pieces. Many such blasts occurred south of Ribblesdale's shaft and were a great nuisance, but north of Carmichael's shaft they became so bad that driving had to be suspended until the blasts played themselves out. The quartz of the reef at this point is 10 ft. wide and shortly after the level was opened for some distance the quartz in the roof commenced to fly off and gradually worked itself out in the form of a wedge tapering from the roof of the level upwards for 8 or 9 ft. The effects then ceased or became so diminished that it was possible to resume work and timber up the roof. In this case the 1940 ft. level is the bottom level but one, the ground being intact below save for the 2040 ft. level and intact above up to the 1840 ft. level. In fact there is practically no stoping at all for a long way above the point referred to, the ground being intact right up to the 540 ft. level except for Carmichael's shaft itself and the levels running from the shaft. There is therefore practically no pressure of importance on the quartz forming the roof of this level such as would be the case if much of the reef had been stoped out in the neighbourhood. Neither can the pressure due to mere depth be sufficient to

described, we must seek for some other causes for these phenomena. I may say at once that I am quite sure that "air-blasts" have no connection with any store of air or gas in the rock and that nothing which can be properly regarded as a blast or explosion of any kind occurs. The word "air-blast" is a miner's term for a phenomena which resembles the effect of firing a shot in so far as it is accompanied by noise and by the displacement of rock, but there, in my opinion, the resemblance ceases.

It is quite another matter to go beyond this and explain what an air-blast is and how it is caused and at present I have no simple or satisfactory explanation to offer, but I shall briefly allude to a few suggestions.

Mr. Bosworth Smith, in the notes which I have quoted above, suggests an analogy between the air-blast and a Prince Rupert's drop and I do not think that any one who has observed the two phenomena could fail to be struck with their similarity. In the one case we have a drop of glass which owing to sudden cooling is in a condition of intense internal strain and in which these strains result in tensions tending to contract the outer skin or sheath of the drop and which strains maintain their equilibrium only so long as the outer skin remains intact. As soon as the outer skin is injured, or fractured, equilibrium is destroyed and the unbalanced strains cause a disruption of the whole mass resulting in the reduction of the drop to powder usually accompanied by an audible crack or report. In the case of the air-blast we have a portion of rock—whether quartz, black rock, or dolerite dyke—which is in a condition of strained equilibrium and which on disturbance of this condition of equilibrium flies into larger or smaller fragments or even into powder.

The case cited by Mr. Bosworth Smith (Case 2), in which a portion of black rock flew to powder, and the disappearance of small pieces of quartz into powder, which I myself observed (Case 1), point to a very close analogy between the air-blast and the Prince Rupert's drop. It is true that in the majority of cases what is observed is the report and the fall or throwing out of pieces of rock, but this only means that the internal strains are less minutely distributed than in the two former cases or that they are sufficiently relieved at the boundaries of the projected masses to permit of the latter remaining intact for the time being. Further, it may be remarked that the case cited by Mr. Bosworth Smith is exceptional in that the only thing that occurred was th disruption of a small piece of black rock and that several good sized pieces of the rock had been projecte outwards at the same time it is more than doubtful if h would have observed the fact that a small piece had gon to powder.

In the cases which I myself noticed in quartz (Case 1 the observations were by no means easy or pleasan Standing with my back to the footwall I could see th quartz which formed the bottom of the stope cracking an becoming white and opaque, while every now and then small piece would fly off with a loud crack. After some tim I ventured close to the quartz face, shading my eyes wit my fingers, and observed a series of small curved crack come into existence with a crinkling noise. These crack were disposed in a fringe round a translucent piece c quartz about 1¼ ins. long by 1 inch wide. While thes were forming a small piece about one eighth of an incl in diameter on the left side twinkled out leaving a smal cavity and a few moments afterwards a similar piece oı

the right top disappeared. After this I got up and watched the spot while listening to the small blasts going on around. About five to ten minutes afterwards the central piece flew out towards my left front with a crack like a gun cap From these observations I conclude that the quartz was in a condition of strained equilibrium, that the equilibrium was slowly being disturbed and re-established disruptively and that the disruptive effects were marked by the formation of cracks, the flying to powder of small fragments and the projection from the face of larger fragments. In these phenomena we have illustrations of all the effects which are described in connection with these air-blasts with due allowance for variations in magnitude.

It seems to me that the phenomenon of small pieces flying to powder disruptively as seen by Mr. Bosworth Smith and by myself makes the analogy with the Prince Rupert's drop a very strong one and it may be as well to point out that in all probability this phenomenon is a constant concomitant of air-blasts, even though it has been specially observed only in two instances. In Mr Bosworth Smith's case it was the sole effect and in my case it was noted only because the strained area was very closely watched. As a rule cases such as those observed by Mr. Bosworth Smith would pass entirely unnoticed and few people would feel called upon to examine an incipient air-blast as closely as I did in the instance cited. While therefore the minute disruption into dust is probably common in air-blast localities, the fact that it has not been more frequently noticed or recorded is easily explained.

If, then, it is admitted that the quartz or black rock or dyke is in a condition of severe strain, somewhat

analogous to that of a Prince Rupert's drop, at those places where air-blasts occur, the next point for consideration is the way in which such strain may be produced.

On this point I have not been able to arrive at any satisfactory conclusions and must content myself with discussing some tentative suggestions and I shall begin by referring to Mr. Bosworth Smith's views as expressed in the note quoted above.

Mr. Bosworth Smith discusses the cause of the strains in the three very different classes of material in which air-blasts have been observed *viz.*, in the quartz, in the trap dykes and in the hornblende schist and his views may be briefly stated as follows:—

In the quartz the strains may be caused by pressure of the walls of the lode. This pressure is not that due to the weight of overlying rock, as I have already shown that the prevalence of air-blasts bears no relation to the variation in superincumbent pressure due to the excavation of stopes, but it is the regional pressure to which the area has at times been subjected and which has resulted in the crushing and folding of the schists and of the quartz reefs. Such pressures would doubtless cause great internal strains in the rocks which would in places be relieved by crushing or movement and would in other places persist as irregularly distributed strains owing to the rigidity of the materials involved.

In the trap dykes it is suggested that the air-blasts are due to strains set up by the sudden cooling of the originally molten material of the dykes and that the effects are more noticeable on the edges of a dyke, where it is fine grained owing to more rapid cooling, than

In the hornblende schist, the presence of small strings of calcite is noted, but the suggestion that this calcite may be the cause of the pressure which gives rise to air-blasts, a favourite hypothesis amongst the mining men on the Field, is rejected in favour of the view that the pressure is in some way due to the metamorphic changes which the schists have undergone, the formation of calcite being a concomitant effect of chemical alteration.

Finally Mr. Bosworth Smith sums up in the following words—

"Whether the schists of the Kolar Gold Field exist as a sharp synclinal fold or not it is undoubtedly true that they have been subjected to an enormous east and west pressure and that where this has not been relieved either by proximity to the surface or to some loose fissure underground the schists and the included dyke and vein rocks exist in a state of great strain and the removal of the enveloping pressure allows these *outward pushing strains* (if they may be so called) to exert themselves more are less rapidly and to disintegrate the rock."

I will now examine the views above expressed somewhat more in detail and I may begin by stating that the explanation that these air-blasts are essentially due to internal strains resulting from the enormous pressures ' which these rocks have so obviously been subjected h for a long time appealed to me as being in the mı correct and up to comparatively recently I should ha agreed with Mr. Bosworth Smith on this point. F some time past however I have been in considera

doubt as to whether the explanation is a satisfactory one and without attempting to arrive at any final solution I shall endeavour to present some other suggestions for consideration and to criticise the views expressed above

Firstly, then, as to air-blasts in the Trap Dykes.

Trap dykes.

Mr. Bosworth Smith's suggestion that these are due to strains set up by the cooling of the molten dykes appears to me to be very reasonable and very sound. We know that the trap has cooled and contracted and the chances of strains being produced during contraction are great. The fissuring or jointing of lavas and dykes is, I think, largely due to internal strains due to contraction which have exceeded the limits of strength of the rock and have caused rupture. The dykes on the Kolar Field possess well marked systems of joint planes and the blocks formed by these planes exhibit spheroidal weathering in a very marked degree. This jointing and spheroidal weathering is noticeable for a considerable distance below surface, but is of course most marked on surface and where surface waters have circulated. It may be contended that these features are entirely due to weathering, but personally I am inclined to believe that they are essentially due (particularly the well marked spheroidal shells) to internal strains which tend to cause the joint blocks to assume the spheroidal structure, the actual development of such structure being either only potential or remaining invisible until the blocks come within the sphere of weathering agencies.

If this be correct, it is not difficult to understand why portions of a dyke when broken into underground should sometimes fly off or scale. The breaking down of a dyke by explosives would doubtless effect the relief of

many of the strains near the exposed surfaces and would cause re-arrangement of others which in favourable cases would cause pieces of the rock to crackle and fly. I have seen pieces of concentric shells scaling off the face of a perfectly fresh dyke at a depth of about 1,000 feet from surface, though there was no indication of any general concentric structure in the rock.

If, then, the strains which cause air-blasts in the dykes are due to contraction on cooling the molecular condition of the dyke material must be very different to what it would be if the whole mass were in a condition of regional compression as suggested in the last quoted para of Mr. Bosworth Smith's note. If the one explanation is sufficient to account for the phenomena, the other is unnecessary. We might suppose the dyke to have been internally strained during cooling and afterwards to have been subjected to great compression along with the surrounding rocks, in which case the latter pressure would be removed at the point where an opening was made into a dyke below ground and there the original strains would re-assert themselves and produce the blasts unless they had been obliterated by molecular re-arrangement. Even in such a case the phenomena would still be essentially due to the contractual strains modified, perhaps, by the compressive strains within the dyke material. Apart from such an assumption it is more important to note that the dykes on the field exhibit none of the usual signs of having been subjected to great pressure and which are so obvious in the surrounding schists and quartz reefs; they are not at all schistose and under the microscope the constituent minerals show no signs of crushing or deformation. The dykes are much younger than the schists and quartz reefs and have been injected into two sets of cracks or fissures,

one set running north and south and the other east and west, and, though the molten material may have been under considerable pressure at the time of injection, there is nothing to show that the dykes have been subjected to any pressure after solidification ; on the contrary it is more probable that owing to cooling and contraction the pressures within the dyke mass are negative and tend to cause the formation of joints and cracks.

With regard, therefore, to air-blasts in the dolerite dykes it will be seen that I agree with Mr. Bosworth Smith in supposing them to be due to the internal strains set up by contraction on cooling from a molten state, but that I do not agree that there is any evidence to show that the dykes have been subjected to pressure since soldification or that the air-blasts are due to strains due to compression.

Hornblende Schist.

I next pass on to the question of the strains in the hornblende schists which constitute the country rock of the Kolar Gold Field. These schists are for the most part fine grained holocrystalline rocks consisting of hornblende, felspar and sometimes quartz, usually with a schistose structure. They are the metamorphic representatives of a very ancient series of diabasic and basaltic lava flows which have been folded into a sharp syncline by great east and west pressures and in which the original augites have long since completely changed into hornblende. No one can for a moment doubt that these rocks have been squeezed under enormous pressures at some period of their history and, if it is found necessary to assume that they are now in a condition of great internal strain, it is not unnatural to jump to the conclusion that such strain is a residual

effect of the compression which is known to have taken place. This is the view taken by Mr. Bosworth Smith who considers that these compressional strains still persist locally, having been relieved in places by movement or crushing of the rock material or in other places by the formation of loose fissures. It is also the view which I myself favoured until recently, but of which I am now inclined to doubt the correctness.

We must admit that at one time the rocks were under great regional pressure sufficient to bend them into sharp folds and to cause slow viscous movements in places. At the time when such pressure was active there can be no doubt that the present rocks were buried under a great thickness of superincumbent schists which have since been removed by denudation and it is quite certain that this active pressure has long ago ceased to exist. The question remains as to whether the intense condition of strain which must have existed throughout the mass of the rocks at the time when the pressure ceased to be active still persists or whether it has been partially or wholly dissipated. I am inclined to believe that not only has it been wholly dissipated, but actually reversed so that the rock instead of being in a state of compression, is in, what may be loosely described as, a state of internal tension.

Let us consider the history of the rock for a moment. First of all we have a great thickness of basic lava flows which by earth movements became crumpled up into great folds and more or less sheared and deformed. The earth movements, which were probably very slow and prolonged, gradually ceased and the folded lava beds underwent slow metamorphic alteration. The principal feature of this alteration is the change of the augite into

hornblende—a change which is probably accelerated or facilitated by pressure. If it is true that this paramorphic change (using the term in a wide sense) is helped by pressure, it is probable that the accomplishment of this change very largely reduced the internal pressures in the mass. I may here refer to Mr Bosworth Smith's suggestion that the metamorphic changes which these rocks have undergone may have given rise to the internal pressures causing strain and which he appears to use as an alternative or additional hypothesis to that of regional pressure, and I may observe that it merely presents the alternatives of considering either that pressure produces metamorphism or that metamorphism produces pressure, and in the present instance I prefer the former. Assuming then, that the change from augite to hornblende was produced or at least helped by the pressure under which the rock existed and that much of the intensity of this pressure was *pari passu* relieved by the molecular reconstruction of the minerals, the next point to be noted in the history of the rock is the intrusion of the great neighbouring masses of granite and gneiss. I have elsewere* shown reasons for supposing that much of the granite and gneiss on either side of this narrow belt of schists is intrusive towards the latter If this view is correct the intrusions must have raised the schists to a considerable temperature probably with further modifications of the crystalline structure. On the cooling and shrinkage of the granite masses whatever regional pressure may have existed at the time of intrusion would be relieved and the heated schists would at the same time have cooled and contracted. Without

* *Vide.*—Appendix to Report of Chief Inspector of Mines 1899, and Records of the Mysore Geological Department. Vol. III, Pages 16 and 40.

stion of how many separate intrusions took place there appears to me to be in the above noted sequence of events to the great original folding pressures etely removed and even reversed giving ssures in place of positive ones within hists. Leaving out of account for a ion of the fissures which the quartz e may pass to the latter and final stage e introduction of the dolerite dykes. believing that these dykes cut their tightly compressed mass of schists or nd adjacent gneisses were violently two rectangular sets of planes now kes. The cleanness of the dyke walls, arcity of fault breccias and the trifling which has taken place are all against think it much more probable that the nature of a series of great joint planes contraction, possibly assisted by gentle w, and filled quietly with molten dyke is certain that at the time of intrusion surface level of the country was much surface and that whatever tensional ne schists at that time have since been han diminished by the reduction of quent on the closer approach of the wards the surface or more properly ach of the surface towards the schists.

tion of the tendency of the schists to , to be found in the behaviour of the surfaces underground. No matter how ppear when first exposed, they rapidly

develop joints and scale off in large slabs and this effec is increased by the introduction of dry air. This appear to me to be more consistent with shrinkage of the expose surface after removal of the resistance of the adjacent roc than with the tendency to swell and burst outwards unde the influence of internal compression.

Finally as to the presence and influence of calcite, agree with Mr. Bosworth Smith in rejecting this as a effective cause of the strains which produce air-blasts and in fact I am more than doubtful whether air-blasts are a marked when veins of calcite are present as when th schist is free from them and compact and homogeneou "Airing" of the rock where veins of calcite are numerou is common enough, but I doubt whether this phenomen can be properly classed with air-blasts such as occur i quartz, trap or solid black rock or if so only to a subsi diary extent.

Again the numerous veins of calcite appear to me rather as an indication of the tendency of the enclosing schists to contract and form fissures and the calcite itself which is a soft mineral, is usually clear and crystallin and does not appear to be either capable of inducing grea local pressures or of existing in such form in the crack of a rock suffering from severe internal compression. Al of these considerations lend colour to the suggestion tha the schists have undergone contraction in the past and that they still may have local tendencies to contact further.

Quartz.

Lastly there is the question of the condition of strain in the quartz itself in which these air-blasts are observed more frequently than in either the schist or the trap. This

frequency may be an indication that the strains which produce air-blasts are more numerous or more strongly developed in the quartz than in the other rocks, but on the other hand such may by no means be the case and the frequency may be due partly to the fact that more work is done in the quartz and partly perhaps to the physical characters of quartz being more suitable for production of air-blasts than is the case with schist or trap.

Bearing these alternatives in mind let us consider the past history and present condition of the quartz. It is generally admitted that the quartz reefs are fissure veins occupying cracks or introduced along planes of weakness approximately parallel to planes of schistosity of the country rock. In places there are folds in the reefs, though their character has not been very clearly made out, and in places the quartz has a finely granular texture which may have been produced by crushing. Under the microscope the grains of quartz show strain phenomena, whatever their nature or origin may be, and it is generally admitted that the reefs have at some time or other been subject to considerable pressure. The important question, however, is whether such pressure still persists or whether in spite of a general relaxation of pressure portions of the quartz remain in a condition of compressive strain. I see no reason to think that the quartz is at present in a state of compression except such as may be due to the weight of overlying rock while the presence of joints and cracks in portions of the reefs, the introduction of calcite and quartz in secondary veins and the redistribution of metallic minerals along joint planes all seem to me to point to contraction after the formation of the reefs. It is true that there are *slikensides* in many places some of which may have been produced by pressures

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of the trap dykes, there is no evidence of its ever having been severely compressed after solidification while it is probable that simple cooling and contraction has produced a condition of internal tension, and that in the other two classes of material it is quite possible that after the cessation of deforming pressures (that is, before the introduction of the trap dykes in Cuddapah times) secular cooling and contraction may well have led to the formation of joints and fissures and in the more solid portions to a tendency to further contraction which exhibits itself in air-blasts when portions of the surrounding envelope are removed. The latter hypothesis appears to me to be more in accord with what I know of the character of these air-blasts than the former, but even if this be admitted it can be regarded as only a very partial explanation of the phenomena.

We know practically nothing of the differences between air-blasts which occur in trap, schists or quartz, but I have no doubt that there are specific differences and further observations helping to define these would be very useful. It would be interesting to know whether trap dykes on other fields exhibit corresponding phenomena and whether the same have been noticed in quartz reefs lying in similar or in different enclosing rocks. Again, the fact that the schists have at one time been subjected to great regional pressure must not be lost sight of; even if such pressure is not the immediate or principal cause of the strain which gives rise to air-blasts it may have had an important influence on the character or distribution of the strains set up by subsequent contraction. I trust that in thus drawing attention to this matter at some length some valuable data for comparison will be forthcoming from other mining areas.

Quakes.

I pass now to a description of certain larger pheno-
na which are common in some of the Kolar Mines and
ich are usually reported as air-blasts. I think that
y are distinct in character and origin from the air-
sts which I have already described and I purpose to
;inguish them by the term "quakes" as in many
pects they partake of the nature of small earthquakes.
aking generally, a quake may be described as a local
ture of some portion of rock underground, giving rise
an earth tremor which may be felt on surface at
onsiderable distance from the point of origin—in some
es to between 3 and 4 miles. The quake is accompanied
a noise or report, frequently audible on surface for a
e or more from the origin, the precise character of
ich is rather difficult to ascertain. I have never heard
myself and the accounts given to me vary. Some
ple describe the noise as similar to the explosion of a
vy charge of gelatine; others as suggestive of the
wing up of a distant magazine, while others hear merely
indefinite rumble. Such differences are only to be
ected and depend largely on the situation of the
erver, whether within doors or in the open and whether
r any shaft through which the sound may come or
ed so that only the indefinite rumble which probably
ompanies the earth tremor is heard.

These quakes appear to be of very frequent occurrence.
comparatively few are of such magnitude as to attract

general attention or to cause much visible damage underground. The larger and more striking ones are practically confined to two mines, *viz.*, Champion Reef and Ooregum, which occupy the middle section of the Champion Lode. The following record which has been maintained in the Champion Reef Office shows how many of these quakes have been noticed from November 1901 to June 1903.

Champion Reef Gold Mine.

REGISTER OF UNDERGROUND AIR-BLASTS. (*Quakes.*)

Date.	Hour.	Remarks.	Date.	Hour.	Remarks.
27-11-01	5 a.m.	...	7- 6-02	10-40 p.m.	...
Do.	8 a.m.	...	25- 6-02	9-38 p.m.	Heavy.
2-12-01	8-30 p.m.	...	25- 7-02	4-10 a.m.	Heavy followed by another slight.
4-12-01	4 p.m.	...	...	...	...
11-12-01	6-45 a.m.	...	28- 7-02	6-55 a.m.	...
Do.	9-15 a.m.	...	21- 8-02	11-45 a.m.	Do.
Do.	11-20 a.m.	...	2- 9 02	4 a.m.	Heavy.
Do.	11-27 a.m.	...	9- 9-02	8-35 a.m.	Do.
18-12-01	4-35 p.m.	Heavy.	15- 9-02	1-45 p.m.	Do.
23- 1-02	1-50 a.m.	...	Do.	4-42 p.m.	Do.
30- 1-02	10-20 p.m.	...	25- 9-02	3-15 a.m.	Very heavy.
2- 2-02	5-50 a.m.	...	6-10-02	12-10 p.m.	Do.
6- 2-02	1-10 a.m.	...	18-10-02	12-40 p.m.	*Very* heavy.
7- 2-02	8-10 a.m.	...	20-10-02	10-10 a.m.	*Very* heavy.
14- 2-02	3-55 p.m.	..	24-10 02	11-52 a.m.	...

besides being accompanied by a noise,
' tiles, shaken down plaster from the
furniture--such as a high book case—

the effects of the larger quakes may be
ollowing cases in which I have secured
rmation and several of which I have

was first attracted to the subject by the
report of a large air-blast which had
occurred about the 760 feet level in
: southern boundary of the Ooregum
iation received was that a very violent
rred which had blown out the candles
ire sinking the shaft a few feet below
; that large quantities of rock had been
that a considerable portion of the shaft
The shock was both heard and felt at
people.

fects appeared to me to be altogether
of an air-blast, so far as my knowledge
and accordingly I visited the scene of
ay after its occurrence in company with
t, Mr. Bullen, and Mr. Arthur Taylor
eld at the time.

'late II, Fig. 3) shows the situation at
It was being constructed on an underlie
ugh the old stopes near the southern
Ooregum property. Between the 660
vels the shaft was carried through a bar
k which had been left standing in the old

stopes. At the time of the accident the bottom of the shaft was a few feet below the 760 foot level and the shaft had been completely timbered down to that level. On examination after the accident, it was found that about 30 feet of the shaft immediately above the 760 foot level had been bodily shifted southwards from 1 to 3 inches (Fig 2, Plate II), four of the end pieces (9 inch square new timber) on the north side of the shaft (A A) and several lining planks had been smashed like matchwood, the footwall of the shaft just below the level (C) was shattered and raised in great slabs and several props (B) in the 760 foot level were broken and displaced. Some 20 feet inside the level, a large gaping crack was found extending upwards into the arch of black rock immediately above some broken props. From the damage visible and from an examination of the plans, it seemed clear that the origin of the shock lay within the wedge shaped arch of rock occupying the corner north of the shaft and immediately above the 760 foot level. The pressure on this arch was no doubt very great owing to the amount of stoped ground to the north of it and above and below it and eventually it gave way causing the damage described The shock felt at surface was probably due to the sudden give of the hanging wall and the sound may have been caused by the production of the large rent shown in the sketch. With regard to the fracturing of the footwall of the shaft at the point C, it is probable that an intense vibratory motion due to the momentary relief of pressure by the break up of the supporting arch of rock would be sufficient to displace several slabs of rock.

A study of this case led me to the conclusion that the quake shock was different from an ordinary air-blast, not only by reason of its magnitude, but in its mode of origin,

the former being due to the disruptive relief of strains produced by superincumbent presure, while the latter is, as I have already shown, due to strains existing in the rock material prior to and essentially independent of the development of pressure due to adjacent excavations.

In all the other cases of quakes which I have investigated I have found the same general conditions to prevail and each case has tended to confirm my original conclusion. I will now briefly describe a few other cases in the order in which they have occurred.

Case II.

On the 8th of November 1900, a big shock occurred in Garland's shaft, Champion Reef, between the 740 ft. and 840 ft. levels and was both felt and heard at surface. About 70 feet of the shaft was damaged, as shown by the dotted lines in Fig. 4, Plate II, the timber being shifted slightly to the north and most of the end pieces being smashed or bent. It will be seen that the shaft passes through a large pillar of quartz with much stoped out ground on either side and that the pillar is weakest where the damage occurred. The shock was no doubt due to the sudden giving way of the portion of the pillar between the 740 foot and 840 foot levels under the weight of the hanging. I did not see the place myself and cannot speak to the condition of the pillar after the shock; it was said to be much fractured at the sides of the shaft, but the outsides of the pillar were not visible as the adjacent stopes had been filled with dead rock. The fact that the stopes had been filled with deads is an important point. As soon as I had come to the conclusion that these quakes were due to the giving way of pillars under pressure, I pointed out the desirability of obtaining more support in the neighbourhood of passage ways by more extended filling of stopes

with black rock and much more filling has been done during the past two or three years than was the case previously, especially in Champion Reef and Ooregum. I hoped that careful filling would obviate these severe quakes, but this expectation has not been fulfilled. Quakes have continued to occur, though it is probable that their number has been reduced and probably also the severity of those which have occurred. Even if filling will not entirely obviate quakes, there can be little doubt that it helps to minimise their after effects and to lessen the chance of any section of a mine closing up as the result of the giving way of some supporting pillar.

Case III.

On the 3rd of January 1902, a fall of quartz occurred in the 940 foot level, Ribblesdale's shaft, Champion Reef, shown at x, Fig 5, Plate II, the quartz which fell being indicated by vertical shading. This again was in a pillar of quartz through which the shaft passes, the stope immediately to the north of the pillar being filled with black rock. The displacement might from the situation be regarded simply as a heavy fall of ground, but from the statements of several Europeans who were in the level at the time as to the loudness of the report and from the fact that many of the timbers in the shaft alongside were broken and crushed, I am inclined to think that the fall originated in fracture due to crushing. I have known much bigger falls to occur without giving rise to any loud report or causing any noticeable shock.

Case IV.

A very severe quake occurred on the 28th January 1902 between the 1,060 foot and 1,160 foot levels at the southern boundary of Ooregum, See Fig. 3, Plate II. Here an old pillar (P)

forming the barrier between Ooregum and Champion Reef was being removed when suddenly a portion of the pillar (quartz) gave way and was badly shattered, much of the timber in the stopes on the north side was broken and displaced, a good deal of the hanging wall came away and the foot wall was shattered and thrown up in large slabs. There can be no doubt that the cause in this case was the sudden fracturing of a portion of the pillar under the top weight which is here very great owing to the extensive stopes on either side. The stopes were very heavily timbered, but no amount of timbering seems to form any safeguard in such cases, though it doubtless helps to keep the stopes from closing altogether.

Case V.

On the 30th January 1902 there was a big smash in Rowe's shaft, Champion Reef, between the 900 and 1,000 foot levels, see point x in Fig. 3, Plate II. The shaft here passes through a large dolerite dyke with some quartz left standing alongside. The quartz and some of the dyke gave way forcing about 50 feet of the shaft in a northerly direction (as shown by dotted lines), as much as 3 feet in places and smashing the shaft timbers. This is, I think, a clear case of pressure on the dyke and pillars of quartz owing to the excavation of the neighbouring stopes. The shock was distinctly felt at surface.

Case VI.

On the 11th March 1902 a very severe quake occurred near the 1,160 foot level on the southern boundary of Ooregum—see Fig. 2, Plate II. This was just below the place where case IV occurred and was undoubtedly due to the giving way of a further portion of the same pillar (P) which was being stoped away. Much damage was done to the timber and walls

of the 1,160 foot level and the shock was very strikingly felt at surface.

Case VII

On the 5th June 1902 in the 1,040 foot level south of Glen shaft, Champion Reef,—see from x to y of Fig. 6, Plate II. This was a very severe shock and was felt in some of the bungalows at surface as far as two miles away from the shaft. It was feared that about 100 feet of the level had come together, but afterwards it was found to be only filled with debris. The roof of the level was heavily timbered and much of the stope above filled with deads. Much of the timber was smashed and the hanging and footwalls damaged Near the point x several timbers were displaced and a quantity of deads ran down into the level. By far the greatest damage occurred below the pillar P where the timbers were completely smashed and the level quite choked up with rock and quartz. With the strong pillar P above, one would have expected the damage at this point to be less than elsewhere, unless, as I think must have been the case, the origin of the disturbance was due to the break up of the pillar itself. From the cross section through P (See Fig. 7) it is obvious that a large portion of the hanging is supported by the pillar with a certain amount of assistance from timber and dead rock and that the fracturing of such a pillar would produce the effects noted

Case VIII.

A severe shock occurred at Champion Reef on the 13th of March, 1903 in a stope below the 900 foot level south of Rowe's shaft —see the spot marked y on Fig. 2, Plate II. This stope is on the south face of a large dolerite dyke which cuts obliquely across the reef from S. E. to N. W. and also underlies to the N. E. The 900 foot level goes through

stope at the time of the accident was p below the 900 foot level and was about and about 30 feet from N to S (See tch, Plate I, which gives a view of the footwall (eastern) side.) In the stope resting on heavy stull pieces (18 to 20 er); the 900 foot level runs along the ipper platform and passes through the point x (Plate I) The second plat-r 15 feet below and a ladder close to the the two The south end of the stope arge *horse* of schist which divides the rts for some distance back The reef the bottom of this stope and tails off in the hanging wall and the oblique dyke, large wedge shaped portion of the stope 1 of dyke shown in section on the right he lower corner of the dyke is represent-show the debris at the bottom of the

re shock occurred which was felt at hree miles from the origin, the dyke ired and much dyke and schist were north end into the bottom of the stope

I visited the stope a couple of days t in company with Capts. Poole and opean timberman who was in charge of ent at the time of the accident. The noise and concussion was terrible, all out and great quantities of rock fell, being filled with dust. He seemed thing in the end of the stope had gone attering the dyke and throwing pieces

of rock about. The two Captains were more or less of the same opinion and Capt. Poole drew my attention to two planks knocked out of the upper staging and sticking up obliquely as shown in the sketch and to a large piece of schist resting against the footwall of the level close by. He regarded this piece of schist as having been blown up from the stope below, through the staging, knocking up the two planks on its way. Before we left I think we agreed that such an explanation was unnecessary as well as being practically impossible. In the first place the piece of schist could have come, and no doubt did come, from the hanging wall above the level. It was too big (about 24 by 18 by 8 inches) to get through the hole in the staging without squeezing and neither the stulls nor the planks showed any signs of having been struck from below. Finally the planks were held in their oblique position by some large pieces of dyke which had fallen on their ends and there can be little doubt that it was the weight of these pieces of dyke which had originally raised them into that position.

Again a portion of the lower staging had been knocked away during the smash and one of the large stulls (D) was found lying at the bottom of stope. I gathered from those who were with me that it was their impression that this damage was due to something bursting upwards and outwards from the lower end of the stope and throwing the timbers about. On the other hand, I myself am of opinion that the timber was knocked out by falling rock coming obliquely down from end of the stope behind the portion of dyke shown in the sketch. At the bottom of the stope some large blocks of rock (B) were found which consisted of a peculiar variety of schist which had evidently come from the wedge shaped end of the stope next

› and which would have knocked alling.

ing point of the whole case is con-ece of the same schist which was the timbers at the south end of the the lower staging (see A in sketch). ghed over half a ton, was said to om the north end of the stope to it smashed the ladder shown there. old of rocks being thrown about by ned this point minutely and came there could be no doubt whatever had been violently projected from of the stope and that it must have low trajectory. I had the evidence harge of the stope that the piece the quake and that it was found ls, in the position shown, with the the broken off portion of the ladder nbers behind it. Nothing had been it and the conclusion that the rock ›wer few feet of the ladder appeared ›le, the northern side of the ladder that the rungs projected on the out-ee inches. Again, the piece of rock acter with that in the northern cor-here some loose and shattered pieces it would have been quite impossible k to have fallen into such a position pe was closely timbered over by the ly a small ladder opening. I have at the rock in question came from

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The next case occurred on the 20th March 1903 in a stope below the 1,085 foot level south of Rowe's shaft, Champion Reef,—See point z, Fig. 2, Plate II. In this stope the south face of the big dyke mentioned in the previous case was also exposed and suffered a considerable amount of fracturing, large flakes being thrown down from the face of the dyke into the stope. A well marked shock was felt at surface, but below ground no great amount of damage was done and I refer to the case chiefly because of its association both in time and place with the previous case. The same dyke was here affected in a similar manner though to a lesser degree and the latter case may perhaps be regarded as partly due to the former.

Case IX.

On the 2nd of June 1903 a severe shock was felt at Champion Reef at about 8 p.m., just about dinner time, and the shock was so noticeable as to cause several people to start up from the table and make for the doors. Plaster fell from the ceilings in several bungalows and the vibration was noticed as far away as Road Block—about 4 miles from the origin. The origin of the quake was in the 1,340 foot level, south of Ribblesdale's shaft, just where the cross-cut from Tennant's shaft meets the level. (See Figs. 8 and 9, Plate II). Just here there is a loop in the level, the eastern or main level being on the main lode which has been largely stoped out, as shown in Fig. 8, while the western branch or loop is simply a level in solid country there being no stoping above or below it. On inspection I found that the principal damage extended from x to y in the main level a distance of about 140 feet. All along here, the floor of the level was raised and the tram line bent and tilted up. The foot wall was much fractured

Case X.

and large slabs up to 12 inches thick were raised from it, the most marked effects being about the point C where there was only just enough space left between the displaced footwall and the hanging to crawl through. The hanging wall, as frequently noticed in other cases, was much less damaged than the foot wall, though many shales and large flakes had fallen from it. The roof of the level consisted of closely set stulls (14 to 18 inches in diameter) with lathing on top supporting the "deads" which filled the stopes above. Many of these stulls were crushed, bent or thrown down. The corner B of the wedge between the two levels had suffered considerably and the schist there was crushed and crumpled as though it had been forcibly compressed in the direction of the dip. In the loop level much damage was done at A on the foot wall side, where, as in the main level, the foot wall had been thrown out in huge slabs.

This case puzzled me considerably at the time of inspection, as I was informed that the reef had all been stoped out for considerable distance above and below the main level and I was therefore unable to see what had given rise to such a violent quake at this particular spot. On examining the plans afterwards with Mr. Stonor, the Surveyor of the Mine, I found that all the quartz had not been stoped out, but that a large pillar (P) had been left for support between the points x and y (see Plate II, Figs. 8 and 10). This at once enabled me to account for the quake in conformity with the conclusions which I had deduced from previous cases and I think there can be no doubt that this pillar had given way under the overload causing the damage which I have described. This case is therefore a further confirmation of the hypothesis that

quakes are due to the giving way of pillars under the superincumbent weight.

Conclusion.

The foregoing ten cases are, I think, sufficient to show that the larger air-blasts, or quakes as I prefer to call them, are essentially connected with and are in fact due to the sudden giving way of pillars or bars of solid rock in localities where much stoping has taken place. All of those of which I have received details have occurred either in Champion or Ooregum. I am informed that there have been some in the Mysore Mine, but they do not appear to have been severe and were not brought to my notice. None have occurred in Nundydroog or the other mines to the north thereof.

A complete explanation of the location of these quakes is not obvious and more information is required before it will be worth while to attempt an explanation. It is obvious however that all the cases which I have quoted above have occurred in areas in which much ground has been stoped out, the majority of them being situated not far from the boundary between Ooregum and Champion Reef. In Nundydroog the stoped out areas are less extensive and the reef dips more steeply than in Champion Reef and Ooregum and this may help to explain the absence of quakes in that mine, but the same explanation can hardly account for their absence or infrequency in the Mysore Mine where there are very extensive stopes and where the reef is flatter than in Champion Reef and Ooregum. The question of the general distribution of quakes therefore requires further examination.

Apart from this point, some explanation is required of the prevalence of quakes on the Kolar Gold Field as com-

pared with other Mining areas. The frequency as well as the severity of the phenomena described above are, so far as I know, peculiar features of the workings on the Kolar Gold Field which are not to be met with in other mining fields Such an impression may be partly due to ignorance of what occurs elsewhere, but I have not heard of or met with similar occurrences on numerous other fields with which I am acquainted. Possibly, however, the fact of my calling attention to the occurrence of these quakes here may elicit information as to their occurrence elsewhere and an examination of varying conditions under which they occur may help towards a better understanding and more complete explanation of them.

One of the first points upon which some more precise information is wanted is the character of the sound which accompanies a quake and the immediate cause of it. As might be expected, the descriptions which I have received very greatly, much of the variation being probably due to the location at the moment, as well as to the personal equation, of the auditor. There would no doubt be a considerable difference in the sound as heard by those below ground from that which is heard on surface, but there is often a doubt whether these two sounds have the same origin or vehicle of transmission. I have come across many cases in which a well marked report heard below ground has passed quite unnoticed on surface, which of course is not difficult to understand, and several more remarkable cases in which a sound distinctly audible at surface has failed to attract the attention of those working in the mine, and I am inclined to think that the sounds most frequently heard below ground are those due to the sudden rending or fracturing of rock which in most cases fail to make themselves heard on surface while the

sounds which are well marked on surface are due to vibrations set up by the sudden jerk of the hanging consequent on the fracturing of a pillar and transmitted to surface through the overlying rock with the production of an audible vibration as well as a perceptible tremor.

The next point for enquiry is the reason for the prevalence of these quakes on the Kolar Gold Field when compared with other fields. In the Champion Reef and Ooregum Mines very large sections of the reef have been removed down to a depth of about 1,700 feet, the workings being on an underlie of about 50°, and undoubtedly the extent of these workings and the comparatively low underlie tend to produce great pressure on pillars and other supports of the hanging wall, more so than perhaps than is the case in the majority of gold fields. On the other hand there are certainly both gold and coal fields where the pressure on pillars must be as great as or greater than here and where, so far as I know, quakes are not prevalent and the inference must be that though pressure is essential, it is not sufficient to cause quakes except under special local conditions. Such local conditions are, I think, to be sought in the physical characters of the rocks forming not only the pillars but also the adjacent country rock and it will probably be found essential that these rocks should be both hard and brittle within certain limits, that, in fact, they should be capable of withstanding very considerable pressure without appreciable deformation, but that once a certain limit of pressure is reached, they should yield suddenly. The conditions are remarkably fulfilled on the Kolar Gold Field by the quartz, the dykes and the black rock, that is to say, by all the rocks present. If the material forming the pillars is not sufficiently strong or if the hanging and

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reason why such filling should be discontinued or abated. It is probable that the filling has in many cases greatly diminished the after effects of a quake and that by taking up the pressure over a larger area it will tend to diminish other quakes in the same locality. If it is true that pillars are an essential factor in the production of quakes the obvious policy would be to leave no pillars and to support the hanging walls of stopes by timber and deads only, allowing the worked out parts to close down as soon as possible. But there are many practical difficulties in the way of carrying out such a policy. In some cases what are virtually pillars are left, because the stuff forming them is not wanted and their removal means expense—for example transverse dykes and patches of barren ground—but on the other hand I would recommend mine managers to consider the advisability of not leaving pillars for the express purpose of supporting ground, but rather as far as possible to do without them and to trust to keeping open any necessary spaces by means of timber and careful filling in of dead rock.

There is one more point to which I may refer. It has frequently been noticed in the case of large quakes that the foot wall has shown much more signs of damage than the hanging wall and the way in which the footwall has been thrown up in places has, I have no doubt, much to do with the popular impression that the quake was due to something in the footwall which caused the rock to burst up. The bursting up of the footwall is, as I have tried to show, an after effect of the quake, a side issue in fact, and not the primary feature. If we suppose a pillar to be under a very heavy compression we may regard the hanging and foot walls as slightly dented at top and bottom thereof. When the pillar yields there will be a momentary

relief of pressure during which the dented portions hanging and foot walls will spring inwards setting up el tic vibrations. The vibration in the hanging side is dou less what is left and heard at surface and it tends shake off loose pieces from the hanging wall in the vi nity of the quake. As the hanging wall is usually k

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BULLETIN

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THE

Occurrence of Secondary Augite

in the

KOLAR SCHISTS

BY

W. F. SMEETH, M.A., D.Sc.,

State Geologist and Chief Inspector of Mines.

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CONTENTS.

THE OCCURRENCE OF SECONDARY AUGITE IN THE KOLAR SCHISTS.

I.—CHARACTER AND MODE OF OCCURRENCE OF THE AUGITE.

Introductory.

For some years past I have had occasional opportunities of examining the Kolar Belt of Schists and have lived in hopes of finding time to publish some account of this interesting series of rocks, but up to the present I have not been able to take this work seriously in hand.

In the year 1900, I published a short account* of the general features of these schists which may serve as an introduction to the present paper in which I propose to deal with the mode of occurrence of the mineral augite in the hornblende schist. I am induced to treat this question separately here instead of delaying it any longer for inclusion in my proposed report on the Kolar Belt, as the evidence which I have to record appears to me to be of more than local interest and may possibly prove valuable and suggestive to students of petrology generally.

The main contention of the paper is that the augite in these hornblende schists is of secondary origin and derived from the hornblende. I am unable to say exactly how novel such a proposition may be, as my opportunities for referring to literature on the subject are meagre; I am

* "Notes on the Geology of the Kolar Schists and Surrounding Rocks." Appendix to the Report of the Chief Inspector of Mines in Mysore for the year 1899.

aware that augite has occasionally been noted as a secondary mineral in cases of contact metamorphism, generally in connection with limestones, and that its occurrence in veins and amygdules in certain basic lavas bordering on the Shap granite has been recorded by Messrs. Harker and Marr* but I do not think that its occurrence as a product of the metamorphism of hornblende schist (itself a metamorphic rock) has been observed or if observed has not been so prominently brought to notice, as the occurrences which I am about to describe would seem to warrant. It is very probable that in most cases the mere association of hornblende with such secondary augite would lead to the augite being regarded as the original mineral from which the hornblende had been derived, owing to the universally recognised tendency for such a transformation to take place. I hope however to be able to show that in the case of the Kolar schists the converse, and less usual, change has taken place and that it has been a wide spread and constant feature in the life history of these schists.

In the present paper I shall confine myself to the Kolar Schist Belt itself, although the same features occur in numerous other patches of schist scattered throughout Mysore, which are so similar petrologically and stratigraphically to the schists of the Kolar Belt that it will probably be found legitimate to include and distinguish them all under one common designation as "the Kolar Series."

General Character of the Schists.

Constitution.

The schists are essentially hornblendic and occur in a series of steeply inclined beds of varying texture. The composition of

* Supplementary Notes on the Metamorphic Rocks around the Shap Granite. Quart. Jour. Geol. Soc. Vol. XLIX. p. 361. 1893.

these beds approximates to that of normal diabases and dolerites. In mineral constitution they are composed of dark green to black hornblende, which is bluish green to yellowish green in thin sections, fairly basic plagioclase felspar and a little titaniferous iron ore more or less altered into leucoxene.

Texture.

In texture there is great variety ranging from coarse to fined grained types comparable to the textures of diabases, dolerites and basalts and like those rocks showing ophitic and intersertal structures; there are also a few members with porphyritic felspars. Many of the beds have however suffered considerable deformation and alteration with consequent loss of original structure and now appear as coarse to fine hornblendic schists in which the hornblendes become more tufted, fibrous, or granular, while the felspars are broken up into granular aggregates of quartz and felspar. The above mentioned types make up the greater bulk of the schists and in addition there are some ampibolites (by which I mean rocks composed practically entirely of hornblende), some hornblende granulites or rocks composed of fairly uniform granules of hornblende, felspar and perhaps quartz, and some banded and veined types.

Origin.

There can be practically no doubt that these schists were originally a series of basic lava flows, mainly of diabasic to basaltic types, which became folded and metamorphosed under pressure into the present hornblendic forms and that very probably the original minerals were augite, plagioclase and titaniferous iron ore.

No original augite left.

The probability that this assumption is true, *viz.*, that the hornblende of these rocks is derived from original augite, is so strong that it scarcely needs direct support, nevertheless a careful search for anything which could be regarded as

residual portions of the original augite was made in all sections which were cut. Over one thousand sections of these schists have been examined and I am satisfied that no trace of any original augite remains; the metamorphism appears to have been very uniform and complete.

Augite does however occur in these hornblende schists in certain cases and sometimes in such a way that, were these cases considered separately and apart from the general evidence obtainable, the augite would undoubtedly be regarded as original.

The object of the present paper is to relate the general evidence which I have so far obtained on this point and which I beleive is sufficient to negative the suggestion that any of the augite now to be found in these schists is original and generally to emphasise the view that augite may under certain conditions be a secondary mineral derived from hornblende. It is probable that the conditions to which I allude may be found to obtain elsewhere than in Mysore in connection with old hornblendic schists.

Location of Augite.

Augite associated with intrusive acid material.

By far the most important part of the evidence relates to the localities in which the augite is found to occur. These localities are all distinguished by the fact that in them the schists are invariably associated with more acid material, which latter is, in my opinion, of an intrusive character.

The accompanying sketch map shows the southern portion of the Kolar Belt of schists and it will be noticed that the schists are lying in an extensive area of granitic rocks, either granites or granitic gneisses, which are, in my opinion, later than the schists and intrusive towards them. In the belt close to its eastern border there is a

series of highly crushed granitic rocks which I have previously referred to† as the "conglomerate series." The name is not a good one as the series does not, in my opinion, contain any true conglomerate. I shall however retain the name in this paper and refer to the series as "the Conglomerate Series" merely stating at the same time my opinion that the rocks comprising it are essentially intrusive with regard to the schists.

Very briefly then we may be said to be dealing with—

(*a*) a series of basic hornblendic rocks steeply inclined, more or less schistose, and collectively referred to as "Hornblende Schists;"

(*b*) a series of highly crushed granitic rocks lying mainly within the boundaries of the hornblende schists and intrusive towards them and called the "Conglomerate Series ";

(*c*) a great extent of granites and granitic gneisses surrounding and in places intruding the hornblende schist which may be conveniently referred to simply as "Gneiss" or "Granite."

In addition to these main divisions it may be noted that both the conglomerate series and the gneiss are penetrated by later veins and bands of aplite and pegmatite which sometimes penetrate the schists and also that both the conglomerate series and the gneiss contain included bands, lenses and fragments of the hornblende schists. A glance at the sketch map attached to this paper will enable the distribution and relationships of the above mentioned series to be more easily followed.

On this map I have placed a number of red dots to indicate the localities where augite has been found and a

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† "Notes on the Geology of the Kolar Schists and Surrounding Rocks." Appendix to the Report of the Chief Inspector of Mines in Mysore for the year 1899.

glance at these dots shows that the augite occurs chiefly near the borders of the hornblende schists. This is true of all the localities shown with the exception of numbers 3, 4, 8, 9, 11, 21, and 29 and the map might be made very much more striking if a special survey were undertaken to determine as many localities as possible where augite occurs. As it is, the dots simply show those places in which augite has been found in the ordinary course of survey work. Of these the majority are associated with the conglomerate series, most of the others are associated with the gneisses of the western border and the exceptions already noted are associated with schists which have suffered alteration and are either veined or banded with acid material. This association of the augite with acid materials of more recent origin than the schists is sufficiently striking, but it becomes much more forcible when it is pointed out that not a trace of augite has been found in the great bulk of the schists which exhibit no such alteration and which retain to a large extent their original igneous structure. Were the augites original constituents of the lavas, the most likely places to find them would naturally be in those members of the series which have suffered least alteration, that is to say, in the coarse to fine grained hornblende diabases, which still retain the lath shaped felspars and ophitic structures of the original lavas, or in the homogeneous hornblende schists, which are rocks of similar composition without such characteristic igneous structures, but the fact is that in none of these has a trace of augite of any kind been discovered, although several hundred microscope sections of these types have been carefully examined.

Augite only in altered Schists.

Broadly stated then the evidence is as follows:—that in an extensive series of hornblendic rocks all of which are of more or less similar composition and all of which are most probably of similar origin (*viz.*, basic lava flows originally containing

augite with perhaps some tuffaceous members) the fact that the augite now found in these rocks is invariably located only in the more altered varieties which are veined, banded, or otherwise associated with subsequent (intrusive) acid materials, while the less altered homogeneous varieties are invariably free from augite affords evidence amounting to proof that the augite is a secondary mineral and that it is genetically related to the intrusions of acid material into the schists.

Augite derived from Hornblende.

Further than this it must be conceded that the augite is formed at the expense of the hornblende of the schists which brings us back to my original proposition that the augite is a secondary mineral derived from hornblende and is therefore a reversal of the widely recognised change of augite into hornblende. Whether the change is comparable to uralitization or not I am unable to say; the augite crystals certainly do not represent original hornblende crystals, so far as their shape and boundaries are concerned, but I am inclined to think that there has not been much change in composition, but rather a molecular re-arrangement combined with aggregation or segregation as the augites are as a rule larger than the hornblendes from which they have been derived.

With this general statement as a prelude I will now briefly describe some of the specimens containing this secondary augite and will divide these into two series *viz.*,

A. a series of specimens intimately associated with the conglomerate series and

B. sundry other specimens from the body of the schists.

Description of Specimens.

(A) Associated with Conglomerate Series.

No. 2. (J_1/488). *Locality.*—In nulla running N. E. from 5/55 on Patna-Betmangala road; 3½ furlongs north of road.

Description.—The crushed granite of the conglomerate series at this point contains several lamps and patches of hornblende schist which are much banded with granite, pegmatite and aplite. The specimen is from one of these acid bands and is fairly granulitic in texture with much granular pale green augite and a little hornblende. Numerous tiny granules of sphene present. No Ilmenite.

No. 6. (J_1/154). *Loc.*—2½ furlongs south of Pitchpalli.

Des.—Similar generally to No. 2. The augite grains are poecilitic in structure enclosing granules of quartz and felspar. Grains of brownish sphene present. No Ilmenite.

No. 12. (J_1/198). *Loc.*—Nearly two furlongs west of Surpalli.

Des.—A banded hornblende schist close to the conglomerate series. The hornblende is in granular aggregates and prisms lying in finely granular felspar and quartz with small specks of ilmenite partly altered to sphene. The lighter bands are indefinite and contain pale green granular augite with felspar, quartz and sphene.

Note.—The number preceding the description refers to the numbered dots on the map. The number in brackets is the number of the specimen in the departmental collection.

The iron ore in these rocks is usually titaniferous and is throughout referred to Ilmenite although some magnetite may be present.

No. 13. $(J_1/292)$. *Loc.*—One furlong S. W. of tank bund, 7 furlongs N. N. W. of Madmangala, in nulla.

Des.—The specimen is from a fine grained semi-granular hornblende schist with acid veins close to the conglomerate series. The specimen is faintly banded; the lighter indefinite bands contain large poecilitic plates of greenish augite. There is much sphene dust and a little muscovite. No Ilmenite.

No. 15. $(J_1/463)$. *Loc.*—Seven furlongs east of △ 3071 close to conglomerate series.

Des.—This is an acid intrusive vein or band in hornblende schist consisting of quartz, decomposed felspar and plates of colourless to greenish augite with some pyrites and a very yellow epidote (?). No Ilmenite.

No. 17. $(J_1/346)$. *Loc.*—On rise 3½ furlongs W. of Chikkalhalli. It is about two hundred yards away from the conglomerate series, but the banding of the schists is probably due to the latter.

Des.—A coarse hornblende schist with numerous lighter bands consisting of granular quartz, felspar and pale green augite. A little muscovite and calcite present and much granular sphene No. Ilmenite.

No. 18. $(J_1/372)$. *Loc.*—At the base of northern spur of Yerrakonda at junction of schist and conglomerate series. A shaft has been sunk here and specimen is from dump.

Des.—An indefinite schist consisting of ragged scales of hornblende in a ground mass of fine felspar and quartz with much sphene dust. In this there are large patches and streaks of coarser

quartz and felspar with much pale green augite, granular sphene, and pyrites. No Ilmenite.

No. 19. (J_1/499). *Loc.*—Three furlongs S. E. of Δ 3359 (Yerrakonda). Schist in contact with conglomerate series which here contains much pegmatite.

Des.—The schist appears to have been an amphibolite originally. It is now veined in places with epidote and shows much sphene dust and no ilmenite. There are patches of very coarse augite, quartz, felspar and sphene which appear to be due to the influence of pegmatite veins.

No. 25. (J_1/515). *Loc.*—In western branch of nulla 2½ furlongs N. N. W. of Attinatam. Band of banded schist in conglomerate series

Des.—Fine hornblende schist with plenty of granular sphene and no ilmenite. In this are indefinite bands full of pale green augites in groups of optically continuous patches with felspar, quartz and pyrites.

No. 26. (J_1/517). *Loc.*—One furlong west of Pedda-Gollapalli.

Des.—A greenish band in the conglomerate series consisting of granular aplite with grains of pale augite, epidote and sphene and patchy crystals of very blue green hornblende.

No. 28. (J_1/541). *Loc.*—One and a half furlongs west of Gollapalli. Close to conglomerate series which contains much pegmatite and aplite.

Des.—Coarse schist with pitted surface; consists of large greenish augites, granular to poecilitic, with granular quartz and felspar between, some green hornblende some of which is derived

from the augite. Granular sphene, epidote and calcite present. No Ilmenite.

No. 31. (J_1/570). *Loc.*—East flank of Mallapakonda ridge; 3 furlongs S. W. of Kodiganpalli.

Des.—Banded hornblende schist close to conglomerate series, banding probably due to latter. The bands are full of pale green augite in poecilitic patches with epidote, quartz, felspar, granular sphene and pyrites. These lighter bands are almost granulitic in texture.

No. 32. (J_1/576). *Loc.*—Two furlongs east of Buragalpalli.

Des.—A patch of banded hornblende schist lying in the conglomerate series. In the lighter bands (and to a less extent in the darker bands) there is much greenish augite some of which has altered into blue green hornblende. Much calcite and granular sphene present. Ilmenite doubtful.

No. 33. (J_1/583). *Loc.*—In a nulla 3½ furlongs E. N. E. of Pedda Partigunta.

Des.—Tongue of hornblende schist in conglomerate series. The specimen consists of granular quartz with hornblende in fibrous to blade like aggregates and much granular matter which appears to be epidote and augite. A good deal of red brown sphene, calcite and brown mica.

No. 33. (J_1/584). *Loc.*—150 yards north of J_1/583.

Des.—Similar to J_1/584, but fresher and with much of the mica developed.

(*B*) *Sundry other specimens from the body of the schists.*

No. 3. ($J_1/79$; $J_1/996$; $S_2/47$). *Loc.*—Nine furlongs west of 2804 △ (Madamuthanhalli) north and south sides of main nulla. Near the boundary of the Patna granite.

Des.—Fine hornblende diabase with lathshaped felspars and hornblende in ophitic patches or scaly and fibrous aggregates ($S_2/47$) and showing small spots or eyes. In the neighbourhood of the latter the diabase is altered to a finely granular rock containing much pale green augite, while the spots themselves consist of large crystals of the same augite partly altered at the edges into solid green hornblende and associated with quartz, calcite and pyrites ($J_1/79$).

This was the first specimen of the schists in which augite was noticed and it afforded a great puzzle until the secondary character of the augite was recognised, from later work, as well as its association with acid intrusives It still remains a very remarkable type and will bear further description. I may state here however that even before other evidence was obtained the structure of this specimen seemed altogether against the possibility of the augite in these spots being residual portions of the original mineral from which the hornblende of the enclosing mass was derived. It is probable that this curious structural and mineralogical alteration of the rock is due to the near presence of the Patna granite and of the pegmatite veins so numerous near its boundary. The exact boundary is not very clear as it is covered by much soil, but in the main nulla a little north of where these specimens were

taken there is evidence of granitic intrusion with the production of a coarse diorite due to inter-action with the schists. I may also remark that the spots, which at first were regarded as of the nature of amygdules are seen in some sections to tail out into veins and are probably of the nature of knots in these veins and quite possibly are unconnected with any corresponding structural feature in the original rock.

No 4. (J_1/218). *Loc.*—Two furlongs north of *h* in Krishnarajpur, in small nulla running N.N.W.

Des—A fine grained veined hornblende schist portions of which are very full of pale augite in large poecilitic patches with an indefinite groundmass of quartz, felspar, fibrous to scaly hornblende and granules of sphene. No ilmenite.

The specimen is not near the granites bounding the schists, but the extensive veining is an indication of the secondary introduction of acid material. As a matter of fact granite and pegmatite are not very far removed, as these are found intruding the mass of the schists a little further west along the main nulla.

No. 9. (J_1/269). *Loc.*—A few yards east of tramway crossing road north of Glen shaft, Champion Reef.

Des.—Schist with elongated fibrous hornblendes and showing small quartzose stringers with pale augite and a little colourless mica, much sphene dust and no ilmenite; evidently an altered schist the augite being associated with acid veinlets. It is however far away from any granite.

No. 11. ($J_2/5$). *Loc.*—Two furlongs south of Mysore Mine boundary stone (old N. E. corner) and due west of Edgar's shaft.

Des.—Hornblende schist with lighter irregular vein like patches. The hornblende schist is a fairly fine granular variety with some ilmenite altering to sphene.

The lighter patches are full of large poecilitic (ophitic) plates of pale green augite associated with quartz, felspar, calcite, pyrites and sphene the texture being almost granulitic.

This is an interesting specimen, but it is not near any granite and the only thing to suggest alteration is its veined character and mineralogical composition. Taken alone it would be a puzzling case and the augitic portion which is the fresher might be considered as the original phase. It however falls completely into line with the general deductions of this paper.

No. 20. ($J_1/505$; $J_1/507$). *Loc.*—East and west nulla 5 furlongs south of ∆ 3359.

Des.—Irregularly and indefinitely banded or veined schist containing patches of hornblende schist lying between more acid portions containing much pale green augite with sphene grains and dust. The augitic portions are practically granulitic in texture.

No. 21. ($J_1/387$). *Loc.*—Rise about 1 mile S. E. of ∆ 3359.

Des.—Very fine grained hornblende schist with wandering acid veins containing large augite grains with calcite and specks of pyrites.

No. 29. ($J_1/538$). *Loc.*—On east flank of Mallapakonda ridge, 5 furlongs west of Gollapalli.

Des.—Specimen with some small patches of hornblende schist lying in a granular groundmass of pale green augite, quartz and felspar with some sphene and pyrites.

This might be well regarded as an original augitic rock and the only thing to suggest secondary alteration is the presence of fine aplitic veins, in which the augites and pyrites are more largely and clearly developed, and the presence of sphene in place of ilmenite.

Remarks on the general characteristics of the foregoing specimens.

The brief descriptions which I have given of the above specimens will, I think, be sufficient to enable me to draw attention to certain features which they possess in common and by which they are distinguished from the main mass of the Kolar schists It will be seen from the map that a number of specimens have been omitted; these all belong to more or less distinctly granulitic types and an account of them will be given below in a separate section.

Majority of specimens near intrusive granites.

The specimens described above have been divided into two groups chiefly for purposes of emphacising the prevalence of augite in the neighbourhood of the intrusive granitic rocks, in comparison with the occurrence of that mineral in the main body of the schists and this prevalence will be found to be still further accentuated when the other specimens which also occur in proximity to granito-gneissic masses come to be described. The division into two groups, has not been made on account of any difference, either mineralogical or genetic, between the members of the two groups, as I do not believe that any such difference exists.

On the other hand it is quite possible that if the specimens of the "B" group were the only ones in existence the nature and origin of the augite might easily have escaped notice and the mineral might have passed unconsidered as residual augite in casual acceptance of its well known tendency to pass over into hornblende and of its claims to be considered one of the essential original constituents of basic igneous rocks. But in the case of the majority of the specimens of the "A" group the field relations of the augite to the associated granites and pegmatites are so striking as to compel special attention and to lead one unhesitatingly to the conviction that the augite is secondary and that its presence is due to the influence of the acid intrusives. From the petrological similarity of the members of the "B" group to those of the "A" group I am of opinion that the augite in the former must be attributed to the same cause although no mass of acid intrusive rock may occur any where near them.

Petrological character of Main Mass of Schists.

I now propose to consider the essential characteristics of these two groups of specimens and for purposes of comparison I shall begin by alluding briefly to the petrological character of the main mass of the schists which, as I have already stated, do not exhibit these particular characteristics.

The main mass of schists is composed of a series of hornblendic layers or beds which are now steeply inclined owing to folding and which differ from one another in texture. There are all gradations from very coarse to very fine grained types and some porphyritic examples. A great number of them possess characters which are generally recognised as those of igneous rocks, such as lath shaped felspars and an ophitic relationship between the hornblende and the felspar. In mineral composition they consist essentially of bluish green hornblende, plagioclase felspar and ilmenite with occasionally a little quartz.

In structure a great many of the types correspond to diabase, dolerite or basalt and it is fairly safe to conclude that the schists were originally basic lava flows composed of augite, plagioclase and ilmenite. Subsequent metamorphism has altered the augite completely into hornblende and in many cases has done little else beyond imparting a slight schistosity. In other cases there has been greater deformation producing highly schistose types in which original igneous structures have naturally been obliterated with the production of diabase schists and finer grained types. In these latter cases there has been fracture and comminution of crystals and also a certain amount of re-crystallization giving rise to clear felspars crowded with hornblende microliths also to quartz and possibly epidote and causing partial alteration of the ilmenite to leucoxene and in rare and perhaps doubtful cases to sphene.

Homogeneous types contain no augite.

Taken as a whole however the schists are still homogeneous rocks and consist of hornblende, plagioc'ase and ilmenite with in some cases disseminated grains of quartz and partial alteration of the ilmenite to leucoxene. In these rocks there is not a trace of augite, original or secondary and it is precisely in these homogenous types and especially in those which retain their original igneous structure that we should expect to find traces of the original augite were such to be found anywhere. I conclude therefore that the original augite of these rocks the pre-existence of which though hypothetical is so probable that it may be taken for granted has been completely converted into hornblende leaving not a trace behind.

Non-homogeneous types with augite.

Turning now to the specimens of the groups "A" & "B" it will be observed that almost all of them represent rocks which are decidedly not homogeneous, but are banded, veined or patchy and that the augite present is most clearly

related to and most largely developed in the bands, veins and patches and not in those portions which resemble the normal schists of the belt. There is to my mind no doubt that the bands, veins and patches are secondary features introduced into schists previously of normal character and the extent to which the normal character has been altered presents every gradation from those cases in which we have normal schists (sometimes showing original igneous structure) with merely small veins or bands containing augite through others in which the veining and banding has largely increased with increase of augite and alteration of the residual portions of hornblende schist up to cases in which large portions of the rock are augitic and with practically no original hornblende schist remaining. From the close association of the majority of the specimens, including the more altered types, with the conglomerate series I am of opinion that the greater portion of the banding and veining accompanied by the development of augite and other mineral changes is essentially due to the influence of the intrusive granites and pegmatites of that series though later acid intrusions have undoubtedly also produced corresponding results.

Mineral and Structural changes.

I will now briefly review some of the principal changes which may be noted in these altered rocks omitting the already mentioned fact of their non-homogeneous character.

General Character.

Augite.—This mineral which is the most striking alteration product is invariably from pale green to almost colourless in thin sections and of a light to dark greenish colour in hand specimens. In no case does the colour approach the pale brownish to purple tints common in the augites of basic lava flows and abundantly represented on the Kolar Gold

Field in the later dolerite dykes which penetrate the schists. The pale green augite of the altered schists has not at present been analysed so that it is impossible to specify very definitely to what class it may belong. It will probably be found to vary from dispoide to some of the lighter coloured aluminous augites; occasionally omphacite occurs. The alterations of the augite from and to a blue-green hornblende (probably pargasite) which are described below suggest that in all probability much of the augite contains alumina.

Composition.

It is practically obvious that the augite has been formed at the expense of the hornblende of the schists and it would be an interesting point to determine whether the former is a mere re-crystallization of the latter or whether there has been addition or subtraction of material. It would also be interesting, though I fear now impossible, to determine the relationship of this secondary augite to the original augite of the lava flows which have been metamorphosed into hornblende schists. An answer to this latter question cannot be obtained unless some of the original augite is found and so far as my examination goes this is not forthcoming. I am inclined to think, however, from general considerations that the original augite must have been a pale variety with brownish to purple tints which is so common in basic lava flows of diabasic and basaltic character; in fact I do not know of any large examples of diabase or basalt flows in which the original augite is of a greenish tinge rather than of a pale brownish colour. This is a point on which I stand open to correction and on which I should be glad of further information though it is not of any importance to the present paper. Assuming however that the change from the original augite to the present hornblende of the schists was essentially a paramorphic change, as the preservation of original structure and the lack of other alteration products in many cases

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ting transformation and the conditions under which it has taken place call for further comment, but for the moment I am only concerned with possible changes in composition from the resolution of the hornblende to the construction of the augite. It would seem most probable that as this transformation occurs at the time of, and as a consequence of, the introduction of acid materials in a heated condition the augite so produce would be of more acid composition than the hornblendes, unless during re-crystallization such acid material may have been again rejected. Even with this latter supposition it must still be conceded that the menstruum from which the pale green secondary augite has separated was undoubtedly more acid than the magma from which the original augite of the lava flows crystallized and it is an interesting question as to whether this secondary augite is similar in composition to the original augite or not, and if it is whether it possesses similar physical characters. In other words was the original augite pale green or is the secondary augite of different composition or merely of different colour to its ancestor. Part of this question will, I hope, be answered by careful analyses of the hornblendes and of the secondary augites, but I have laid some stress on the point here partly because I have a fancy that the original augite was not green and because I should expect the secondary augite to be more acid than the original and partly because there is some microscopic evidence that conflicts with this latter notion by apparently indicating that the change of composition has been insignificant.

Reversion of secondary augite to Hornblende.

This evidence relates to the fact that the secondary pale green augite has to a variable extent reverted to hornblende and the striking feature of this reversion is that the hornblende so produced is as a rule microscopically indistinguishable from the hornblende of the unaltered schists which latter is presumed to be the result of paramorphism of some original augite. In other words the hornblende which

from microscopical evidence is clearly the result of alteration of grains of secondary augite is of the same bluish green colour and general optical properties as the bluish green hornblendes of the unaltered portions of the schists from which the secondary augite must have been derived. This would seem to show that the secondary augite is of similar ultimate composition to the hornblende which yielded the materials for its formation and suggests the possibility that the original augite with its derivative hornblende (often merely a paramorphic change) as well as the secondary augite and the hornblende into which it has partially (and paramorphically) altered are all of the same ultimate composition. If not it is difficult to explain the similarity of the two hornblendes and we should be obliged to admit the existence of two species of hornblendes of similar appearance but of different composition.

If, on the other hand, the composition is regarded as being identical in the two cases the arguments would at the same time tend to prove that the secondary augite and the original augite were of the same composition and if this implies that they were of the same physical appearance we should thus get back to a series of basic lava flows of diabasic character in which the augite was of a pale green colour. Of course there is no proof in all this, it is chiefly surmise and we do not know enough even about the so-called paramorphic alteration of augite to hornblende to enable us to draw conclusions as to what changes in composition occur if any. Again, even admitting the original and secondary augites to be of practically similar composition, there is no guarantee that the colour, which may depend on molecular arrangement or on small quantities of impurities or accessory constituents, would be the same in the two cases. Notwithstanding all this uncertainty, it is, I think, both interesting and worthy of marked attention that the hornblende into which the secondary augite has partially altered is apparently the same mineral as the hornblende from which the secondary

augite has been derived, in spite of the metamorphic changes which have intervened between the formation of the one and the other and it is further an important piece of evidence in connection with the so-called paramorphic change of hornblende to augite about which, especially in regard to chemical composition, there is still so much uncertainty. A certain amount of direct information may possibly be obtainable from chemical analyses, but it is not easy to secure satisfactory analyses owing to the difficulty of separating augite from hornblende especially when the two are united in individual mineral granules.

After this digression it may be well to briefly review the more obvious changes which have been noted in connection with this remetamorphism of a crystalline schist.

We start with lava flows of diabasic to basaltic character in which the presence of augite is assumed. These under the influence of pressure, and possibly of other widespread aids to metamorphism, have been altered into hornblendic rocks in which the hornblende sometimes retains the structure of the parent augite and sometimes is merely a distributed and re-crystallized representative of the same; the general appearance of the hornblende, which we may designate by the letter *a*, is in nearly all cases the same and is characterised by the prevalence of bluish green tints under the microscope. We have as a result a series of metamorphic holocrystalline rocks of variable texture and schistosity.

Locally, in the neighbourhood of intrusive acid material, these rocks become altered with the production of pale green augite (*B*) from the existing hornblende, the augite grains or crystals so produced being so far as I know, structurally unrelated to the hornblende Subsequently the pale green augite has been partially reconverted into *b* hornblende of apparently the same character as the *a* hornblende, the *b* hornblende being as a rule obviously

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instead of lath shaped felspars and so I have used the more general term "pœcilitic." Now the ophitic structure of augite has long been regarded as a sort of hall mark for a rock which has crystallized from a condition of igneous fusion and the question at once arises whether the secondary augite which I am describing must also be considered as having crystallized from a fused magma or whether our views on the significance of the structure require modification. I am unable at present to give a definite answer to the question, but there are some important considerations involved a reterence to which should I tbink prove interesting and useful.

Is structure due to fusion?

I have said that the augite is developed in connection with igneous intrusions and were this to mean that some of the schist had been fused up and the augite crystallized from the magma so produced the development of an ophitic structure would be regarded as a natural and not unexpected sequence of events. Before accepting such a view we must recollect that the intrusive material is in this case of a granitic character and is frequently of the aplite or pegmatite types which are regarded as being the later emanations from a cooling granatic magma. The whole magma and more especially the later emanations are generally regarded as products of aquæo-igneous fusion to a much greater extent than is the case with the basic rocks and in the case of the pegmatites the aquæous element is generally supposed to play a most important part so much so that it is doubtful whether the more suitable designation would be 'solution' or 'fusion'. Whichever it be, I see no reason why the augite should not crystallize out in ophitic or pœcilitic plates just as micropegmatite forms in the case of quartz and felspar so long as the materials and conditions for the formation of augite exist and that such may exist in acid magmas there is no doubt. It is however well to bear in mind that the conditions under

which the structure of this secondary augite has been developed must differ considerably from those obtaining in the more basic rocks and to bring to notice the existence of the structure under novel circumstances. This will be still further emphacised when I come to deal with the special association of quartz with the secondary augites.

Local character of the effects produced.

To return to the question of the possible fusion or hydrothermal solution of portions of the schist as affording an explanation of the origin of the augite it must be noted that the action, whatever its precise nature, has been very local. In most cases the augite is confined to the veins or bands of acid material or to their immediate neighbourhood leaving the rest of the schist unaltered. It is not therefore a case of the mass of the schist having been raised to a temperature at which the hornblende would melt and it is very doubtful if the acid veins which in some case are very minute would be sufficient to produce any real melting at all especially when far removed from any granitic mass as in the case of the B series of specimens. Also it seems certain that the augite is quite locally derived and has not travelled far, in other words that the whole transformation from hornblende to augite has been a local alteration and that the augite is not the result of crystallization from a magma which has penetrated the schist in veins and brought with it the material for such crystallization from some place where the schist had suffered complete fusion. This is borne out by the intercrystallization of minerals at the edges of the bands and veins and by the localisation in many cases of the augite along the edges of the schist walls instead of its being distributed through the mass of the intrusive material. The change is therefore a local alteration in which some hornblende has been absorbed or resolved and has again segregated out in the form of augite in larger units and often with an

ophitic or poecilitic structure and it must be admitted that the conditions under which this structure has developed are very different to those under which the structure arises in a cooling basic lava.

I now pass on to some other mineral changes which accompany the formation of the secondary augite and the introduction of acid material.

Ilmenite and Sphene.—In the unaltered schists ilmenite is always present and is sometimes partially altered to leucoxene. In rare cases I have noticed a tendency for sphene to form at the borders of tho ilmenite grains, but this has been only in the more highly crushed schists in which there has probably been much recrystallization with separation of quartz. When we come to the altered schists into which extraneous acid material has been introduced, we find that ilmenite is practically wanting and that its place is taken by sphene which occurs as fine dust or as smaller or larger grains. Occasionally in the less altered portions of specimens a little ilmenite is found or small specks of it may be noticed in the centres of grains of sphene and there is no doubt that much of the sphene is simply due to alteration of pre-existing grains of ilmenite. In other cases re-distribution may have occurred and in some cases I think that additional sphene has been introduced with the granitic intrusions. The essential point however is that in the altered schist ilmenite is replaced by sphene.

Pyrites.—The unaltered schists are almost devoid of this mineral or rather the mineral has not been observed in the field and only rarely under the microscope though carefully looked for. It is quite probable however that a little pyrities does exist in the unaltered schists, as analyses show the presence of a little sulphur, or at any rate that it did exist in the original lavas. Pyrites may be noticed in the later dolerite dykes which traverse the schists and in these the presence of sulphur is revealed by analysis and

the unaltered schists are not much different in general composition to the later dolerite dykes. Notwithstanding this it is still true to say that pyrites is scarcely noticeable in the unaltered schists.

In the case of the altered schists it is otherwise, pyrites being frequently observed in the more acid bands and veins associated with the secondary augite as well as in the schists close alongside. Sometimes when pyrites is present sphene is wanting, but this is not always so. Although so clearly associated with the intrusive material, I am not certain whether the pyrites should be regarded as a segregation product from the schists or as an introduced mineral from the acid rocks. I think the latter view the more probable and we sometimes find pyrites developed in the pegmatites of the granite and gneiss away from the schists. Sometimes however the specks of black iron ore in altered schist appear to be partially altered to pyrites.

Calcite.—This occurs sparingly in the unaltered schists and then only as microscopic alteration products of the lime-soda felspars. In the altered schists, though not always present it is frequently a conspicuous constituent and probably results from the action of carbonic acid emanations from the intruding granitic material The unaltered schists contain a high percentage of lime (about 12%) and the secondary productions of calcite is a form of alteration which would be naturally expected.

Epidote.—Epidote is a common alteration product of the schists. It occurs in association with altered and probably re-crystallised felspar and also in minute veins traversing the schist. It is however rarely seen in the more homogeneous types but where the schists are banded or veined the development of epidote is of common occurrence and it is particularly associated with the altered schists containing augite. From a mineralogical point of view the epidote is interesting. Occasionally it is pleo-

chroic with strong yellow to colourless tints; sometimes it approaches ordinary pistacite of yellowish green colour in sections, but most frequently it is whitish grey in colour with strikingly weak double refraction giving bluish grey to honey yellow tints in polarized light. There seems to be quite a series of these epidotes with marked gradations in optical properties and doubtless with corresponding changes in chemical composition and I have no doubt that an independent study of them would prove of interest. Zoisite has not been observed with certainty but some of the minerals noted very probably correspond to clinozoisite.

Mica.—This mineral is not a constituent of the unaltered schists, but it is a frequent alteration product in the neighbourhood of intrusive granites. I do not propose to refer here to the larger examples where, as a result of such alteration, micaceous schists have been produced, but to confine myself to the association of mica with local alterations containing augite. In several of the specimens described above the presence of mica may be noted. Sometimes this is a white mica which is not of particular interest and is probably a constituent introduced with the granitic material. Sometimes also a green mica occurs which seems to be an alteration product of the hornblende and which may occur elsewhere if closely looked for and there is also occasionally present ordinary black biotite similar to the biotite of the adjacent gneiss. The particular mica to which I wish to draw attention here is of a bronzy colour with reddish brown tints in thin sections which occurs in some of the specimens already described and which is most probably the result of the action of the intrusive acid material on some of the hornblende of the schists. I merely note its occurrence as one of the characteristic minerals associated with the altered augitic types of the schists.

Garnet.—This likewise is not found in the unaltered types and it does not happen to occur amongst the specimens which I have already described. Nevertheless it is

to be found in several localities clearly associated with acid intrusions into the schists and sometimes associated with the secondary pale green augite.

Apatite.—I have very rarely noticed apatite in the unaltered schists and it is very inconspicuous. In one of the altered specimens described above apatite is abundantly present and other instances could be adduced showing the association of apatite with intrusive granitic material. The mineral is a constituent of the surrounding gneiss and is probably introduced into the altered schists from this source.

Recapitulation.

In the preceding section my principal object has been to bring to notice the formation of augite from hornblende as a particular case of the contact metamorphism of hornblende schist by intrusive granite and its subsquent emanations.

I have endeavoured to show that the schists are for the most part homogeneous metamorphic representatives of basic lava flows of diabasic to basaltic character which in the neighbourhood of certain granitic gneisses become in places banded and veined with acid material and are also found as altered inclusions in the body of the gneiss. The field evidence appears to me to point clearly to the gneiss being intrusive with regard to the schists. The microscopic evidence is still more remarkable.

The most striking feature of the alteration which has resulted from the banding and veining of the schists is the local formation of a secondary pale green augite from the hornblendic material of the schist; this augite possesses frequently an ophitic or pœcilitic structure and frequently tends to occur in rounded granules; it also exhibits a marked tendency to revert to hornblende which is apparently of similar character to the original hornblende.

The other mineral changes which have been noted tend to emphacise the veiw that we are dealing with altered forms of the schists and are of such character as to bear out the contention that such alteration is the result of contact metamorphism in the presence of granitic intrusions. These changes are briefly as follows:—

(1) The alteration of ilmenite to sphene.

(2) The introduction or development of pyrites.

(3) The production of calcite bearing in mind the large amount of line in the schists.

(4) The production of epidote.

(5) The introduction of white mica and biotite and the production of a bronze coloured mica locally.

(6) The development of garnet.

(7) The introduction of apatite.

II.—Association of augite with the gold bearing quartz reefs of Kolar.

I now pass to the consideration of the occurrence of augite in association with the gold bearing quartz reefs of the Kolar Field and the evidence to be adduced, though simply a corrollary of the preceeding section, is in some respect more striking than the former, so far as concerns the secondary nature of the augite. A consideration of the few cases of the occurrence of augite in the Kolar Schists which I had discovered in the year 1899, suggested to me the idea that possibly the augite was of secondary origin, as I was unable to satisfactorily regard the occurrence of this mineral as representing residual portions of the original augite of the lava flows. Further, the association of the mineral with acid material, which I had already begun to regard as of an intrusive nature, and in particular with aplitic and pegmatitic forms of such material suggested to me the idea that, if the quartz reefs of the Gold Field were of similar origin to these latter emanations they might possibly afford similar indications of re-action with the hornblende schist in the development of secondary augite.

Secondary augite abundant.

With this idea I visited several of the mines and examined the quartz reefs with the result that I was surprised and satisfied to find a pale green augite, quite similar to that previously described, extensively developed near the border of the larger quartz veins and in abundance where great numbers of thin quartz veins penetrate the schists producing therein a banded structure. Since that time I have come to the conclusion that this pale green augite is *par excel-*

lence the characteristic mineral associate of the quartz reefs of the Kolar Gold Field. Go where one will the mineral may be found in comparative abundance and though it is less conspicuous where the quartz is in wide and solid bodies, being confined to the edges close to the schist, it is almost continuously present and where the reefs split up into a number of thin veins or bands it is so abundant as sometimes to form the principal constituent thereof and is undoubtedly the principal feature, though not the one most widely recognized, of what the miners call "lody matter."

For purposes of illustration and of comparison I give the description of a few specimens.

Description of Specimens.

The following four specimens show the mineral changes which have taken place in the schist in and close to the lode.

No. S/39. *Locality.*—Ooregum Mine. Cross cut going west from 1060 ft. level Taylor's to Oakley's shaft; Schist on E side of level. The level contains lode matter consisting of more or less parallel bands of quartz and schist.

Description.—Hornblende schist consisting of finely granular quartz and felspar with small blue-green hornblendes and larger ragged and patchy crystals of the same. Numerous small specks of ilmenite partly altered to sphene and partly altered to, or associated with, pyrite.

No. S/40. *Loc.*—Same as S/39 but from lode matter in the level.

Des.—Hornblende schist with many small veins of granular quartz. Bits of the schist are similar

to S/39 save that ilmenite is practically absent. The quartz veins contain ophitic plates and granular patches of pale green augite, large elongated grains of calcite and plenty of pyrites and sphene. The schist bordering the veins has been largerly converted into the same minerals.

No. S/41. *Loc.*—Same as above; the specimen is taken from the schist on the west side of the lode.

Des.—Hornblende schist more uniform in texture than S/39 containing sphene with a few specks of ilmenite and pyrites; this is traversed by well marked veins of quartz containing much pyrites and some fragments of hornblende.

Augite and calcite not present.

No. S/42. *Loc.*—Same as above; specimen taken from schist 20 feet west of level.

Des.—Hornblende schist with very abundant feathery and tufted hornblendes and speckled freely with ilmenite.

No sphene or pyrites present.

No. S/63. *Loc.*—The following three slides *a*, *b*, and *c* are from a specimen of lody matter from end of No. 1 E 1060 foot level, Walworth's, Ooregum mine. The specimen consists of hornblende schist banded with augite quartz and bronze mica.

No. S/63*a*. *Des.*—Hornblende schist with much granular sphene, some epidote, a little bronze mica, much pyrites and no ilmenite.

No. S/63*b*. *Des.*—One of the augite bands, the slide shows a little of the same schist as *S/63a* the remainder being very large plates of pale green augite containing numerous granules of sphene, epidote and pyrites as well as cloudy alteration

products and showing a little alteration to hornblende in places. There is a little quartz between some of the augites.

No. S/63*c*. *Des.*—Part of one of the quartz bands. The slides contains large augites similar to *S/63b* and also much quartz and some calcite. In streaks in the quartz are aggregate of augite grains partly changed to hornblende as well as epidote, calcite, sphene and pyrites.

In the above three slides the bands or veins are not sharply defined, but pass gradually from one variety to another.

No. S/64. *Loc.*—From the East Reef 1410 foot level north of Taylor's; Ooregum Mine.

Des.—Hornblende schist with quartz veins. The slides show coarse grained irregular veins of quartz associated with large plates of pale green augite which enclose granular patches and stringers of quartz and felspar. This augite has partly reverted to bluish green hornblende.

The slides also show more granular areas containing greener augite (approaching omphacite) with much brownish pink garnet, epidote, calcite, tourmaline and topaz, a little pyrites and some sphene as well as quartz and plagioclase.

No. S/93. *Loc.*—Schist on footwall of lode 60 feet South of Taylor's; 1740 feet level; Nundydroog Mine.

Des.—Amphibolite consisting of small compact hornblende crystals with pyrites. This is traversed by bands of large pale green augites with brownish pink garnets and some calcite and bronze mica. No quartz visible in the slide.

No. S/97. *Loc.*—Lode 100 feet south of Ribblesdale's shaft 1140 ft. level; Champion Reef Mine.

Des.—This is part of the lode which contains numerous breciated fragments of schist. The schist fragments are amphibolite and consist of greenish coloured actinolite. This actinolite is much paler than the usual blue-green hornblende of the schists and though it is possible that it may represent a particular variety of the schist it is very probable that it is a completely re-crystallized alteration or secondary product therefore. I take this view partly because it does not now exhibit any alteration into augite although the fragments lie right in the quartz reef and partly because I have found veins of similar actinolite penetrating the normal types of schists in the vicinity of quartz reefs. For my present purpose however it is sufficient to notice that augite is not apparent in the specimen, although it occurs in the reef matter not for away, and the description is included here chiefly on account of other minerals which are no doubt due to the action of the quartz reef on the schist These minerals are colourless epidote, calcite and pyrites and it is noteworthy that they are concentrated, especially the first two, round the fragments of schist while the remainder of the interspaces between the fragments are filled with quartz.

No. S/98 *Loc.*—Hanging wall, 2310 feet level north of Taylor's; Ooregum Mine.

Des.—Amphibolite consisting of bluish green hornblende with bronze mica and pyrites. Traversing this is a band or vein of pale actinolite material with pyrites. This is like the pale actinolite of the previous specimen.

No. S/101. *Loc.*—Hanging wall, 2510 feet level north of Taylor's; Ooregum Mine.

Des.—Schist (almost amphibolite) consisting of tufted blue green hornblende with a little felspar and quartz and numerous specks of iron ore. The latter are partly black and partly pyrites the two being frequently combined in the same speck. Traversing the schist are small irregular and branching veins containing granular quartz and plagioclase with a great deal of tourmaline and bronze mica, the latter mineral being chiefly in contact with the schist while the quartz and felspar occupy the middle of the veins.

General remarks on the foregoing specimens.

After the detailed remarks made about the surface specimens described in the preceding part of the paper, it is unnecessary here to do more than call attention to the very striking points of similarity between those specimens and these which I have just described. In these latter we have as the most essential feature the production of augite which is pale green to colourless in thin sections. This is the most characteristic and universally prevalent mineral associate of the quartz reefs. In structure the augite occurs in large plates or in more or less granular forms with a strongly marked ophitic tendency. The individual augite crystals are generally, as in the previous specimens, of much larger dimensions than the hornblendes of the schist in which they have been produced; they are intimately associated with and confined to the immediate proximity of the quartz veins and they are accompanied by the same accessory minerals or mineralogical changes

as the augites developed in the neighbourhood of the granite intrusions on surface. Thus we have ilmenite completely altered to sphene, abundant calcite, plenty of pyrites as well as epidote, bronze mica, garnet and apatite all of which were noted in the previous specimens. The only minerals associated with the quartz veins and not found in the surface specimens are tourmaline and topaz but these exceptions I believe to be merely due to chance as I have found tourmaline and topaz in the conglomerate series and they would probably be found somewhere in association with augite if looked for. I have also noticed a pegmatite vein, lying with the schists in the New Vertical Shaft, Ooregum Mine, which carries abundant Tourmaline. (Sp. S/110.) If there is a difference to be noted between the two sets of specimens it is one of degree, not one of kind, and it may be stated that on the whole the alteration phenomena are more strongly marked in the case of the quartz reefs than in the case of the schists veined and banded with acid material in proximity to the granite. Thus the intensity of the silicification is greater in the former case as we are dealing with quartz veins instead of with granite, aplite and pegmatite as in the latter case. The other minerals associated with the silicification are likewise more noticeable and conspicuous in the case of the quartz veins, the augite is more abundant and obvious, pyrites is much more plentiful and in places abundantly visible, calcite is visible and in places forms large masses, and the bronze mica where it does occur is often one of the essential constituents of the specimens. Although more locally present the same is true of the other minerals, *viz.*, epidote, garnet, apatite and tourmaline.

The evidence thus afforded by the quartz reefs of the Kolar Field is to my mind most striking and convincing in regard to the secondary character of the augite developed in them and in the adjacent hornblende schists. Every one, with perhaps the exception of Dr. J. W. Evans, who has studied the reefs is satisfied that they are of subse-

quent origin to the schists, that they are in fact intrusives (whether by the medium of solution or otherwise) in the schists and the very striking and intimate association of the augite with the quartz taken in conjunction with the complete absence of augite from the homogeneous unaltered schists affords a most satisfactory proof that the augite is subsequent in point of origin to the formation of the hornblende schist as such. These observations completely bear out the inferences already deduced with regard to the presence of secondary augite in the banded and veined schists bordering on the surrounding granites as dealt with in the preceeding section and strongly support the contention that such banding is a secondary feature due to the intrusion of acid material.

III.—Relationship of Quartz Reefs to acid intrusives.

Quartz reefs are perhaps most usually regarded as due to precipitation from heated waters carrying silica in solution and widely divergent views are held as to the sources of both the water and the silica to say nothing of the sources of such minerals as may be present in sufficient quantity to form workable ore bodies. I do not propose to enter into these questions here in any general way, but merely to draw attention to a few points in connection with the Quartz Reefs of of Kolar which are suggested by the foregoing portions of this paper.

Pegmatite and Quartz Veins.

Of late years there has been a tendency to associate some quartz veins genetically with pegmatite and hence with acid intrusives and opinions vary as to how far such quartz veins should be regarded as solidified from a condition of aquæo-igneous fusion or how far pegmatite should be regarded as deposited from an igneo-aquæous solution. Exact limitations of these terms are wanting and it is probable that a gradual transition from one condition to the other is possible and that it takes place from time to time in nature. Thus it is practically certain that as a granite mass on cooling gives rise to more acid pegmatite veins, so by further elimination of the bases it sometimes gives rise to veins composed practically entirely of quartz.

Alaskites.

Various intermediate stages between pegmatites and quartz veins have been found and certain of these have been called "alaskites" by Mr. J. E. Spurr who found numerous examples in Alaska which I believe he regards as being

genetically related to some of the auriferous quartz veins of that region. I have unfortunately not been able to obtain a copy of Mr. Spurr's report which deals with these alaskites and am therefore unable to refer to his observations in detail, but I have little doubt that quite similar rocks are well represented in or about Mysore for which it will be justifiable to employ the name alaskite. A few specimens may be briefly referred to.

W_2/241. A. From between Maklidrug and Subramany Temple in the broken ground due east of the station. This is a pegmatite consisting of white quartz with a little felspar and pyrites. The amount of felspar is variable, but on the whole is much less than occurs in ordinary pegmatite.

W_1/251. A. On the road four miles east of Seringapatam, a small quartzose reef containing a little felspar.

W_2/309. From a rise close to a small village 1½ miles west of Somarandlapalli near the Pertinkonda railway platform. The specimen consists of bluish grey quartz with small decomposed crystals of felspar distributed through it. The felspars which are about 1/16 of an inch in diameter often show crystal faces.

No. 5992. From porcedyke near Kollegal; said to be a vein in a basic granulite. Very similar to the preceding specimen, but the quartz is darker in colour and shows free gold.

S_2/235.—S_2/268—S_2/279 are specimens of quartz veins or bands from trenches on the S. Amble Mining Block Nanjangud. These veins lie parallel to the gneiss and hornblende schist and contain tiny crystals of felspar which are sometimes idiomorphic and sometimes rounded or oval. S_2/279 contains also apatite and is faintly

banded the bands containing in addition a little hornblende and garnet.

All of the above specimens occur in country essentially composed of granite or granitic gneiss though frequently they are immediately enclosed in other rocks. For instance the fourth occurs in a basic igneous rock and the last three all occur in or near bands of hornblende schist lying in gneiss. The inference to be deduced from an examination of the specimens is that residual secretions from a solidifying granite magma may become more and more acid and give rise to a succession of types represented by pegmatites, alaskites and quartz veins all genetically related to the original acid magma and directly derived therefrom and a quartz vein so derived does not, I think, require any assumption as to the downward percolation of meteoric waters with subsequent heating and solution of silica followed by ascension and rediposition of silica to account for its formation. However much part aquæous agency may have taken in the formation of such a vein, the vein must, I think, be regarded as an intrusive of deep seated origin just as much as the granite, aplite or pegmatite derived from the same magma whether the water of such a magma had originally a meteoric origin or not. This does not of course preclude the possibility of the origin of some quartz veins from other sources in which the reascent of meteoric water after dissolving silica may have played an important part without such water having at any time become an integral part of a deep seated magma, but I wish to emphasize the fact that in Mysore, as in Alaska we have gradations from a granite to a quartz vein and that some quartz veins are very probably intrusives directly secreted from a cooling granite magma. This brings me to the particular piece of evidence bearing upon this question which is afforded by the quartz reefs of the Kolar Gold Field and this evidence is, I think, all the more important from the

typical reef-like character of the quartz and from the fact that we are dealing with a commercially valuable ore body.

The quartz of these reefs is bluish grey in colour, clean and glassy and made up of large irregularly interlocked grains except where much crushed. There is no suggestion of pegmatite or alaskite about the material, no felspar being present except in proximity to the schist walls where it can be easily and satisfactorily regarded as derived from the schist by absorption and recrystallization. The payable ore runs in well marked chutes and is associated with base minerals.

So far then, there is nothing to differentiate these reefs from many occurring elsewhere and regarded as due to deposition from solution and nothing to suggest their origin from a granitic magma.

When however we come to examine the secondary changes induced in the enclosing hornblende schists by the introduction of the quartz, as already described, we find numerous features such as, the change of hornblende to augite, the alteration of ilmenite to sphene, the introduction of pyrites, the development of ca'cite, epidote, bronze mica, tourmaline and apatite all of which correspond identically in character and disposition with the changes produced in the same schist by the granitic sills and veins, pegmatites and aplites near the junction of the schists with intrusive granite. This close and striking correspondence in the two case seems to me to afford a very strong argument in favour of the view that the two sets of veins, *viz.*, the quartz veins and the granitic veins, have had a similar source of origin and have been introduced into the schists under closely similar conditions and that if it is legitimate to consider the granitic and pegmatitic veins and sills as igneous intrusious derived from a deep seated acid magma, it is a legitimate sequence to infer that these Kolar quartz reefs are also igneous

intrusions derived from a deep seated acid magma. We have thus two lines of argument which lead to a plausible hypothesis that the Kolar quartz reefs are essentially of the nature of acid intrusives; one a general argument derived from the observed transitions from granite through pegmatite and alaskite to quartz veins which permits the possibility of some quartz veins being igneous intrusives and the other a specific argument which shows that the effects of the introduction of the Kolar reefs into schists are precisely similar to the effects produced by the intrusions of granite and pegmatite. In default therefore of strong evidence pointing to any other origin for the Kolar Reefs (such as precipitation from waters of originally meteoric origin) I am at present forcibly urged to the view that these reefs are igneous intrusions, the offspring of a deep seated acid magma.

In using the word "intrusion" here I am aware that many people do not regard the pegmatite associated with a cooling mass of granite as being properly speaking intrusive. Such pegmatites are frequently considered as due to segregation or to seepage of the residual liquor into cracks in the practically consolidated mass and the fact that the crystals of the pegmatite are largely interlocked with the crystals of the granite walls is regarded as supporting this view. My own experience does not lead me to attach much importance to the interlocking argument which is frequently used to prove that two rocks have consolidated about the same time, as I have often found the edges of distinctly subsequent veins interlocked with the crystals of the enclosing walls except where there has been comparatively rapid cooling of the edges of the vein. Apart from this and admitting that pegmatite is a residual segregation from a partially consolidated granite, it must still be admitted that such pegmatite is essentially intrusive where it passes from the granite into pre-existing rock masses and this it frequently does. Even though

the intruding material may be more of the nature of an igneo-aquæous solution than an aquæo-igneous melt I would still regard it as intrusive and with this reservation I have applied the expression "igneous intrusion" to the Kolar quartz reefs.

In all this I have omitted any reference to the auriferous character of the Kolar reefs and to the fact that they contain gold in commercially payable quantities and I do not propose to comment upon these matters here for, although of the greatest importance in some respects, they are rather beyond the scope of the present paper. I may however observe that the fact of the quartz reefs being auriferous, so far from being a point of dissimilarity from the pegmatites and alaskites with which I have endeavoured to ally them is rather one more point of correspondence for several of the pegmatites and alaskites which have been assayed show perceptible quantities of gold up to as much as one dwt. per ton. There is however a marked divergence in degree and the fact that the Kolar Reefs contain in places sufficient gold to be commercially valuable while the pegmatites and alaskites of Mysore do not is a matter of great interest and importance requiring further investigation. It does not seem to me at all necessary, or even probable, that the results of such investigation should in any way militate against the conclusions already arrived at as to the probable origin of the quartz of the reef.

IV.—Granulitic Types of altered Schists.

In the first portion of this paper I have noted, in the case of many of the specimens described, the tendency for the minerals to assume a granulitic texture where secondary augite has been developed in association with intrusive acid material. The quartz and felspar tend frequently to occur in clear rounded granules and the augite itself often occurs in grains, sometimes with rounded outlines, sometimes with outlines formed of concave curves where moulded on the quartz and felspar granules, and the hornblendes derived from these augites also tend sometimes to form granular individuals. This marked tendency to the development of the granulitic texture in hornblende schists, which close to the same point show no such tendency, is a fact which cannot fail to strike the observer. In the specimens already described the tendency is quite local and the texture is hardly sufficiently extensively developed to permit of any specimen being classed as a granulite but I now propose to briefly describe some other examples of these hornblendic rocks which exhibit a distinct granulitic texture over considerable masses of rocks. Such rocks are widely distributed in Mysore and what I have to say here must necessarily be very incomplete and chiefly suggestive, but will, I hope, direct the attention of other officers of the Survey to some points upon which much more information is desirable.

Local development of granulitic texture.

I shall refer to these rocks generally as "hornblende granulites" as the predominant mineral is hornblende with bluish green to yellowish green pleochroism. Pale green to almost

Hornblende granulites.

colourless augite may or may not be present and where present in considerable amount the rocks might equally well be called "pyroxene granulites" with some hornblende. The essentially hornblendic types are bowever far the more prevalent. There are four main points about these hornblende granulites to which I wish to draw attention and which, so far as I am aware, are fairly novel and the truth of which I hope to be able to establish, or at any rate to help to establish, with the material at present at my disposal; these are :—

(1) That the granulitic texture is of secondary origin.

(2) That its development is due chiefly to the influence of intrusive granite.

(3) That the pyroxene (augite) present in some of the granulites is of secondary origin derived from hornblende under the influence of intrusive granite.

(4) That the secondary augite so produced has in many cases partially and in others wholly reverted to hornblende which appears to be similar to the hornblende from which it was derived.

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(1) Secondary origin of the granulitic texture.

Original granulitic texture.

I may begin by saying that I have no reason to doubt that granulitic textures are original in some igneous rocks. We have in Mysore acid granulites, which are more or less aplites in composition, occurring as bands or veins in the gneiss and also a well marked series of basic dyke rocks of the nature of pyroxene granulites with more or less of the pyroxene altered into hornblende, the texture of which is very probably due to the particular mode of cooling from fusion. Other observers have described similar occurances

elsewhere and Professor Judd has suggested that the texture may be due to movement during crystallization. But while admitting that granulitic textures may be original in igneous rocks which are intrusive, or which occur as deep seated masses, I am not aware that there is any evidence to show that extrusive rocks, such as the basic lava flows from which the Kolar schists have been derived, ever possess an original granulitic texture. So far as my personal experience goes I have not come across any such evidence and in particular I have not found any such evidence in the case of the Kolar schists themselves. These schists in many cases still retain recognizable indications of the textures of the original lava flows and the textures so preserved exhibit considerable variety, but I believe that I am quite safe in asserting that in the body of the schists no rocks are to be found which exhib t a granulitic texture. Frequently the original texture of the lava has been obliterated by deformation and recrystallization and more or less granular schists have been produced and occasionally small portions may be found which might be regarded as possessing a partially granulitic texture. For instance in some of the coarser varieties the large felspars appear to have broken up and to be represented by areas of distinctly granular felspar and quartz, while the large hornblendes are likewise represented by aggregates of stunted hornblende prisms. In such cases the shape of the individual grains may be such as would be found in a granulite, but the state of aggregation in which they are found differentiates them from typical granulites in which the various constituents are fairly uniformly distributed. We might call such examples "granulitic schists" and the fact of their very local occurrence, as well as the fact that they are generally found to pass insensibly into rocks with a distinctly diabasic texture, tends to support the proposition that in the schists original granulitic texture is wanting

Granulitic schists.

and that such approximations to it, as may be found locally, are secondary and due to crushing and recrystallization.

(2) Development of granulitic texture due to intrusive granites.

Granulites in and close to granites.

When we pass from the interior portions of the belt of schist to the edges in contact with the granites and gneisses, which I believe to be intrusive, a general change becomes obvious, inasmuch as the schists lose very largely the lava like textures so common in the interior portions and consist for the most part of more distinctly granulitic schists and of typical granulites. This change is neither universal nor constant, that is to say, granulitic forms are not always found in contact with the granite, but they are so common and so marked as to afford very convincing proof that their structure is due to the influence of the granite. The change is still more marked and the typical granulitic structure more universally and distinctly developed in the patches of schist lying included in the granite beyond the confines of the solid belt of schists and these patches and fragments of marked granulitic type are found to occur not only in proximity to the Kolar belt itself but widely, though irregularly, distributed throughout a large part of the State of Mysore. It appears to me, even without other evidence, that these facts lend the strongest support to the theory that the granulitic texture of these rocks is essentially due to the influence of masses of intrusive granite.

Briefly restated these facts are as follows :—

We find that the Kolar belt of schists does not, in the interior and less altered portions thereof, contain granulitic types but that, very locally, granulitic schists may be developed as the result of pressure and recrystallization with, probably, movement and high temperature as essential

factors also. Where these same schists are in close proximity to masses of granite and granitic gneiss, which for other reasons I regard as being intrusive, the granulitic types of schist become very much more prevalent and typical granulites are also found in comparative abundance. Away from the confines of the belt of schist and lying in granite are numerous patches and fragments of schist, which are regarded as being included fragments of the Kolar schists, and these are very universally found to be granulites of similar composition and character to the granulites found near the edges of the schists belt in close association with the granites.

(3) Presence of augite in the granulites due to intrusive granite.

Granulites with augite.

In some of the hornblende granulites and granulitic schists, of which I have been speaking, both in those which lie within the schist belt near its edges and in those which lie without the confines of the schist belt, augite is sometimes, or perhaps I might say frequently, found. This augite is pale green to almost colourless in thin sections and is, so far as microscopic examination goes, identical with the secondary augite, which I have already described as being developed in the schists in the neighbourhood of acid veins. There is of course the distinction due to texture in the two cases, for, whereas in the latter cases the augite occurs in ophitic plates or in granular groups in material which is only faintly and very locally of granulitic texture, in the former the augite occurs as a granulitic constituent of a more or less perfectly granulitic rock, but apart from this question of association the mineral seems to be identical in the two cases. This identity, though, very suggestive, is however insufficient to prove that the augite of the granulites is a secondary mineral and I therefore proceed to

adduce further evidence on this point. The point will, I think, be admitted to be of considerable importance when it is noted that these granulitic rocks are of a type which would most unhesitatingly be described as "pyroxene granulite" in which more or less of the pyroxene (augite) had been converted into bluish green hornblende leaving variable amounts of the original pyroxene still in evidence and in which the pyroxene would generally be regarded as the original ferromagnesian constituent of the rock: whereas the present evidence is designed to show that though undoubtedly some of the existing hornblende has resulted from alteration of some of the augite, of which portions still remain, this augite itself is of secondary origin and derived from an anterior hornblende which itself was probably the result of alteration of still earlier primary augite. In other words I wish to show that in what appears to be a case of simple transformation of augite to hornblende we are really dealing with a treble transformation of augite to hornblende, hornblende to augite, and again augite to hornblende as well as to point to the reasons for such a series of changes. These changes, it will be seen, quite correspond to those which I have already described as occurring locally in the schists in immediate association with acid veins and where the fact that the veins were subsequent to the schists formed a very strong argument for considering the associated augite to be of secondary origin. In the case of the granulites this particular form of argument is lacking, as the granulites are not necessarily penetrated by veins and the augites are distributed through masses of rock whose only association with acid material is that they lie in or border on granites which are considered to be intrusive with regard to them. In view of what I have already said in the earlier portions of this paper the argument relating to the augite of these granulites may be made very brief. In the first place we must return to the less altered types of schist which

Relations of augite to hornblende similar to those in veined schists.

occur in the main body of the Kolar belt and in which we find no traces of augite and no granulitic texture. As we pass to the edges of the schist belt and outwards to the inclusions in the surrounding granites the granulitic texture becomes not merely well marked, but forms the prevailing type to the practical exclusion of other types of texture and at the same time pale green augite makes its appearance in many cases as an essential constituent. I have already shown that it is reasonable and I think necessary to regard the development of the granulitic texture as due to the influence of the granite upon non-granulitic types of hornblende schist and it appears to me to be very reasonable to associate the simultaneous development of augite with the same agency. This reasonableness becomes much enforced by analogy derived from the earlier portions of this paper in which I have shown that similar augite is produced in these hornblende schists under the influence of intrusive acid veins and still further strengthened when it is remembered that those acid veins tend to produce local granulitic texture however imperfectly. The two series of phenomena appear to be genetically similar and only differ in degree, more homogenous and more widespread effects being prcduce under the influnce of the greater mass action of the granites outside the schists than in the case of the acid veins within the schists. To complete the evidence it is only necessary to show that the subsidiary mineral changes which were noted in connection with the acid veins are likewise to be observed in the granulites containing augite which lie in or close to the granites and this I am fortunately able to do.

Accessory minerals similar to those in veined schists.

Sphene.—This is constantly found in the granulites containing augite and is undoubtedly derived from ilmenite. As a rule practically no ilmenite remains save some tiny dots in the centres of the sphene granules. I am not prepared to say that examples may not be found con-

taining much more ilmenite as the conversion is doubtless a gradual one, but in the specimens which I have examined the ilmenite has practically all disappeared and the constant association of sphene with augite is always a noticeable feature.

Pyrites.—This is not so noticeable as in the case of augites associated with acid veins, but is nevertheless frequently to be found in the granulites and much more frequently than in the unaltered schists.

Calcite.—Sometimes in the granulites, but not a very noticeable constituent as a rule.

Epidote.—Very frequently present.

Mica.—Often present in the coarser varieties especially close to the junction with granite, but as a rule more noticeab'e in granulites without augite.

Garnet.—Often present and sometimes in considerable quantities though few of the specimens from the immediate neighbourhood of the Kolar belt happen to contain the mineral.

Apatite.—Very frequently present.

The above minerals associated with granulites containing augite are precisely those found in the altered schists containing augite and associated with acid veins and which are not found to any appreciable extent in the unaltered schists The whole argument therefore goes to show that these hornblende granulites containing augite, some of which might equally well be described as pyroxene granulites, which were in my opinion formerly hornblendic schists belonging to the Kolar series are altered rocks in which a granulitic texture has been produced and various mineral changes developed quite similar to the changes produced in the schists by intrusive acid veins and I attribute these changes and the granulitic texture to the influence of the surrounding granite which I regard as subsequent to and intrusive with regard to the schists.

(4) The secondary augite has reverted partially or wholly to hornblende.

In the previous section I have noted the fact that the granules of secondary augite have, to a greater or less extent, been converted into hornblende so that in some sections there is little or no augite visible.

Reversion of augite to Hornblende.

All gradations may be found from specimens containing much augite to those containing no augite not only from different outcrops but sometimes in the same rock mass and when specimens are in all other respects similar to each other it seems quite legitimate to conclude that those containing no augite are simply specimens in which the secondary augite once existed but has now completely reverted to hornblende. The conclusion may, I think, be fairly deduced in those cases in which the subsidiary mineral changes, which I have already noted as accompanying the formation of secondary augite, are to be observed. Of these the most constant and characteristic is the alteration of ilmenite to sphene and, where we find sphene in place of ilmenite in a hornblende granulite which shows no augite, I think it will still be legitimate to infer, in the majority of cases, that such a rock has once been through the condition of a *secondary* pyroxene granulite in which the pyroxene, and probably the granulitic texture, was of secondary origin. This is a rather far reaching conclusion and by no means sufficiently proved to permit of its being generally adopted, but it is certainly true in many specific instances amongst the Kolar hornblende granulites and it is a point upon which I have no doubt further information will be obtained by a more extended study of the granulites scattered throughout Mysore.

Primary and Secondary hornblendes similar.

The last point to be noted in connection with these augitic types is that the hornblende derived from the secondary augite is very similar in appearance to the original hornblende of

the schists from which the augite was formed just as in the case of the hornblendes derived from the augites associated with acid veins. This fact is in some ways unfortunate as it limits our powers of determining the areas over which the treble transformation has taken place. Suppose for example that in a mass of hornblende schist lying included in the granite a granulitic texture is developed and that in the central portion of the mass the change has been merely from non-granular to granular hornblende while towards the edges of the mass there has been a change from either non-granular, or granular hornblende to granular augite and that subsequently this granular augite has altered to granular hornblende; and supposing further that this latter hornblende which has passed through the stage of secondary augite were of different colour or appearance to the former hornblende, we should then be provided with a visible means of detecting to what extent secondary augite had at one time been developed in the rock notwithstanding that all such augite had now disappeared. Unfortunately however such variation does not exist and we are left in doubt as to the exact locus of the development of secondary augite although we may be quite satisfied that such development had taken place. Doubtless further work will throw more light on this point, but at present the only indication which may remain of the former existence of a secondary augite is, as already pointed out, the presence of sphene and other minerals which are known to accompany the formation of secondary augite, but which have not been proved to occur only in association with secondary augite. The problem of the extent to which these changes have taken place in any given mass remains therefore indefinite though the fact that such changes have played an important part in the life history of many of these hornblende granulites has, I think, been sufficiently demonstrated.

Hornblende granulites without augite.

So far I have largely confined my remarks to the granulites containing secondary augite, or which I have reason to think did at one time contain secondary augite, and which also contain sphene and sometimes other secondary minerals and in which ilmenite is practically wanting. But there are other types associated with the above and sometimes forming portions of the same individual mass of rock in which there is no augite and little or no sphene, but plenty of ilmenite. These types vary from granulitic schists to typical granulites and have the same general distribution as the augitic types, that is to say, they are to be found very sparingly and imperfectly developed in the body of the schists and abundantly and perfectly de veloped at the edges of the schists and lying in the surrounding granites. In these rocks I see no reason to suppose that they have at any time passed through the condition of pyroxene granulites, though I am not prepared to assert the contrary. It seems to me that they are modifications of the hornblende schists in which there has been complete recrystallization aided, in the more granulitic varieties, by the neighbourhood of masses of intrusive granite. I have little doubt that a more complete study of these rocks will show that they pass gradually into types with augite and sphene, as the influence of the granite becomes more intimate, though it must also be admitted that in some cases the granite has failed to produce any such effect.

Formation of Diorite like Rocks.

There is one further step which may be very briefly noted. In the case of some of the hornblendic inclusions in the granite, as also in the case of some granitic intrusives in the schists, there appears to have been very considerable interaction between the intrusive granite and the hornblendic rock, resulting in the intermingling of the two, probably due to the fusion and absorption of some of the hornblendic material by the granite. Thus, in the case of some inclusions the granulitic texture is found to become coarser as the granite is approached and the rock gradually passes into a coarse hornblendic granite or quartz diorite in which the granulitic texture gives place to a granitic texture and this shades off with diminution of hornblende and increase of biotite into the surrounding biotite granite or gneiss.

Such occurrences are for the most part quite restricted in extent, but I have also found large areas of coarse hornblendic granite, which I believe to be the result of an extensive absorption of hornblendic material by the intruding biotite granites. A description of these latter occurrences is somewhat beside the scope of this paper and they are merely mentioned by way of sequence to the preceding cases and will not be further referred to here.

Description of Specimens.

The following specimens are intended to illustrate the observations of the preceding sections in regard to granulitic types and include those specimens the localities of which are marked on the map by numbers, but which were omitted in series A and B of Part I. The localities of other specimens will be indicated as far as possible with reference to the numbers or other marks on the map.

Definitions.

In these descriptions it must of course be a debateable point as to what should be called a "granulite," a "granulitic schist" or a "granular schist" and without any desire to lay down hard and fast definitions, with which no doubt many people would disagree, I may simply explain in what sense I use these terms here.

The three types are supposed to represent stages in the transition towards a prefect granulite and there must necessarily be overlapping of the types according to taste.

Granular schist.

By a "granular schist" I mean a rock in which the minerals are in small granules with, as a rule, irregular boundaries and do not exhibit recognizable igneous structures. Th granular texture is, I believe, due to crushing and movement combined probably with recrystallization.

Granulitic schist.

A "granulitic schist" is one in which most, or all of the minerals are in somewhat rounded grains or short prisms, the edges thereof being fairly regular and clean. In this respect they correspond to the more typical granulites, but differ from the latter in the fact that the minerals tend to occur in aggregates. For instance the hornblende tends to occur in groups or aggregates of prisms between which are areas of granulitic felspar and quartz. This arrangement seems to point to such rocks being derived rocks composed of comparatively coarse hornblende and felspar in which there has been recrystallization without great intermingling of the minerals during the process. Many specimens which I shall here call "granulitic schists" would, I have no doubt, be called "granulites" by others and I should have no objection; but in the present cases I wish to distinguish this type from the next type.

Granulite.

The word "granulite" is reserved for those types which consist of minerals ditributed more or less uniformly in grains with fairly even clear boundaries. The majority of the grains,

especially of felspar and quartz, are rounded; hornblende and augite may occur as rounded grains, short prisms, or indented grains lying between rounded grains of other minerals. The distinction from the last type is therefore cheifly due to the more uniform distribution of all the constituents as opposed to the occurrence of some of the constituents in well marked aggregates.

Granular Diorite.

I may add a remark as to one more type which is referred to as "granular Diorite" and which appears to be a very coarse form of granulite in which the definite rounded character of the grains is wanting and the texture approaches that of a granite or diorite. With these explanatory definitions I now pass to a description of a number of specimens which are grouped according to the localities in which they occur. A second grouping according to type would be of value, but I omit this as any one can show the locations of the various types by playing different coloured dots on the map to represent them.

(a) Specimen from body of schists.

J_1/194. *Locality.*—In the schists half a mile west of Masika.

Description.—*Granulitic schist* consisting of elongated aggregates of hornblende prisms alternating with patches of granulitic felspar and with a little quartz. Black iron ore in strings of granules.

I place this specimen first as an example from the body of the schists at some distance from any visible granite; it is 2½ furlongs west of the granites of the conglomerate series. It is the most granulitic type which I have come across from the body of the schists away from the edges of the belt and it may be noted that it is of very local

extent and that it passes gradually into non-granulitic coarse hornblende diabase. It bears out what I have already said as to such granulitic schists being derived from diabasic rocks of coarse texture and as to the granulitic texture not being original. The coarse hornblende diabase has been schisted and crushed and the locally produced granulitic schist shows the traces of such schistose structure in the elongated aggregates of which it is composed, though the component minerals show very little evidence of crush or strain owing presumably to the fact that they have recrystallized when assuming their present granulitic form

(b) Series showing progressive development of granulitic texture.

The next four specimens are intended to show the progress towards a granulitic type near the edges of the schists as the granite is approached. They are taken from a trench about one mile east of Dasarhoshalli and half a mile north of the Bowringpet road and represent the narrow strip of schist lying between the quartzite ridge and the western granites.

S_2/32. *Loc.*—Schist just west of the quartzite* ridge.

Des.—Fine *granular schist* consisting of granular felspar in somewhat irregular grains, short to elongated prisms of hornblende and black iron ore in granular strings.

S_2/33. *Loc.*—Schist 50 yards west of above.

Des.—Medium coarse *granular schist.* Hornblende in large plates breaking up into granular aggregates alternating with patches of very granular or granulitic felspar with small horn-

* This is the ridge of hæmatite quartzite or ferruginous quartz schist which runs from north to south close to the western edge of the schist belt.

blende prisms. Black iron ore in granular strings.

$S_2/34$. *Loc.*—Edge of schist next to a band of micaceous granite, 50 yards west of above.

Des.—Similar to above, but hornblende aggregates more granular and felspar in more distinctly rounded grains. *Granulitic schist.*

$S_2/36$ *Loc.*—A little west of above. Bands of schist alternating with crushed granite.

Des.—A *granulitic schist* similar to $S_2/34$, but somewhat coarser and more granulitic and showing some quartz. This is a typical granulite save for state of aggregation of the hornblende.

These four specimens, with perhaps the exception of the first, show a gradual progress towards a typical granulitic texture as the granite is approached, the most distinctly developed type occurring as included patches in the granite.

(c) Various types in and close to western granite and gneisses.

The next group includes various types from near the western edges of the schists north of the Madras Railway.

$J_2/8$. *Loc.*—No. 1 on map. North-west side of quartzite ridge close to granite.

Des.—Very *granulitic schist* almost a granulite. Consist of pale augite in granules and ophitic patches, granular quartz and felspar, a little hornblende and granular sphene. No iron ore.

$J_2/9$. *Lcc.*—A little east of $J_2/8$.

Des.—*Granular schist* consisting of granular quartz and garnet with green hornblende in granular patches and very pale amphibole in grians and ragged crystals. Many of the garnets have central cores of brownish 'yellow meterial

which is probably orthite. This is a peculiar and very altered type, which will require separate description elsewhere; it is introduced heic on account of its very granular texture.

J_1/967. *Loc.*—No. 5 on map. A patch of schist in the granite one furlong N. N. W. of △ 3006.

Des.—*Granulite* consisting of granulitic felspar and large, granules and prisms of hornblendes; also pale green granular augite partially altered to hornblende, sphene in colourless grains and crystals, many having a central dot of iron ore and some pyrites.

In texture this is on the border line between a typical granulite and a granulitic schists.

J_1/968. *Loc.*—Patch in granite ¼ mile east of No. 5 on map close to edge of schist.

Des.—*Granulite,* hornblende in slightly elongated prisms, granular sphene with dots of ilmenite and some epidote; augite doubtful.

J_1/969. *Loc.*—2 furlongs N. N. E. of above in the schists close to boundary.

Des.—*Granulite* similar to J_1/968.

J_1/974. *Loc.*—No. 7 on map. In the schists near boundary.

Des.—Fine *granular schist* with a little hornblende; much pale augite in grains and ophitic patches, crystals and veins of epidote, sphene dust and good deal of pyrites.

J_1/976. *Loc.*—5 furlongs south of No. 7 on map. In the schists close to quartzite ridge.

Des.—*Granulitic schist* or more properly a banded granulitic amphibolite consisting of alternate streaks of hornblende granules and granules of felspar and quartz with some black iron ore.

$J_1/979$. *Loc.*—No. 10 on map, schist close to boundary.

Des.—Finely *granular* hornblende schist with pale green augite in grains and ophitic plates and in veinlets associated with quartz and calcite. Much sphene dust; no ilmenite.

$J_1/985$. *Loc.*—Nearly 1 mile S. S. W. of No. 10 on map. Inclusion in granite.

Des.—Fine grained *granulite.* Much hornblende in slightly elongated grains moulded on quartz and felspar. Some epidote and specks of ilmenite altering into leucoxene.

(d). Specimens from south-western limb of the schist belt.

These specimens lie in or close to the granites and gneisses bordering the band of schists running from the Madras Railway Line to Mallapakonda.

$J_1/535$. *Loc.*—In the schists west of quartzite ridge and close to granite about 1½ miles E. N. E. of Battalhalli.

Des.—Typical *granulite,* slightly schistose, with granular sphene, epidote and pyrites. No ilmenite.

$J_1/553$, $J_1/554$. *Loc.*—No. 27 on map. Inclusion in granite.

Des.—Both specimens are coarse hornblende *granulite* with granular sphene and no iron ore. $J_1/554$ shows in addition some pale green augite partly altered into hornblende.

$J_1/569$. *Loc.*—Close to edge of schist next to conglomerate series, about 3 furlongs N. of No. 31 on map.

Des.—Highly *granular schist,* hornblende in granular aggregates, some black iron ore.

J_1/581. *Loc.*—Tongue of schist 1 furlong west of No. 33 on map.

Des.—Banded *granular schist* with much sphene and some pyrites and calcite.

J_1/582. *Loc.*—Patch in granite a little east of above.

Des.—Fairly good *granulite* with brownish sphene and quartzose veins.

J_1/587. *Loc.*—No. 34 on map, upper dot.

Des.—Partly granular amphibolite and partly fine horn-blende *granulite* with colourless augite in granular ophitic patches, also granular sphene and epidote. There are also some quartzose veins containing pale green to colourless amphibole, black iron ore and garnets.

J_1/588. *Loc.*—No. 34 close to granite.

Des.—*Granulite* with rather elongated hornblendes. Also pale augite partly altered to hornblende, sphene, epidote and apatite.

J_1/591. *Loc.*—Close to edge of schist 3 furlongs N. W. of No. 34 on map.

Des.—A banded rock, darker bands containing granular omphacite, pale green augite and granular hornblende alternating with fine granitic bands containing omphacite. Sphene and Pyrites present. This is an uncommon type, but on the whole granulitic in texture.

J_1/601. *Loc.*—No. 30 on map-inclusion in gneiss.

Des.—*Hornblende granulite* banded with granite and quartz. The granulite contains a good deal of brownish garnet, a little sphene and no iron ore.

(e) Specimens from the South-East limb of the Schists.

J_1/329. *Loc.*—¾ of a mile east of △ 3359 (Yerrakonda); schist on east side of a tongue of the conglomerate series.

Des.—*Granulitic schist* with large hornblendes breaking up at edges into grains and prisms and lying in a matrix of granulitic felspar and hornblende. Black iron ore present in grains and strings.

J_1/382 which is ½ mile south of this is very similar.

J_1/344, J_1/345. *Loc.*—Close to edge of conglomerate series a little S. S. E. of No. 17 on map.

Des.—Highly *granular schists* granulitic in parts with much sphene.

J_1/345 contains also calcite and apatite. No. 17, previously described, is similar but contains more acid bands with much augite.

J_1/347, $J_1$348. *Loc.*—A little west of No. 17 on map.

Des.—*Granulitic schists* generally similar to J_1/329.

J_1/354, J/$_1$355. *Loc.*—Edge of schists 1 mile west of Kempapur.

Des.—J_1/354 is fine grained *granulite* squeezed and containing specks of black iron ore.

J_1/355 is coarser *granulitic schist*, almost a granulite. Black iron ore in strongly marked bands probably secondary.

J_1/361. *Loc.*—¾ of a mile slightly west of north of No. 23 on map.

Des.— Highly *granulitic schist* with grains of black iron ore and some epidote.

$J_1/362$. *Loc*—A furlong or so south of $J_1/361$.

Des.—Fine grained squeezed *granulite*, with much granular sphene.

$J_1/364$. *Loc.*—No. 23 on map-schist next to eastern gneiss.

Des.—*Pyroxene granulite* consisting of granular augite and felspar and a little quartz, hornblende, sphene and pyrites.

$J_1/366$. *Loc.*—3 furlongs south of No. 23 on map.

Des.—Coarse hornblende *granulite* with a little black iron ore, hornblendes in irregular grains lying between round grains of felspar.

$J_1/386$. *Loc.*—2 furlongs north of No. 20 on map.

Des.—*Granulitic schist* almost granulite. Ilmenite altering into sphene. Some granular quartz present in eyes and veinlets.

$J_1/416$. *Loc.*—Inclusion in granite a few miles east of Madmangala.

Des.—Coarse typical *granulite*. Contains granular brownish sphene and traces of residual pale green augite in the hornblende granules.

Compare $J_1/201$ which is a very similar inclusion from a quarry about 1 mile east of Madmangala, but rather coarser in texture and approaching a *granular diorite*.

$J_1/422$. *Loc.*—Same region as $J_1/416$, a band in the gneiss

Des.—Similar to $J_1/416$, but coarser though still distinctly granulitic and with more of the pale green granular augite from which the hornblende appears to have been derived.

$J_1/243$. *Loc.*—Schist midway between 23 and 24 on map.

Des—Fine grained granulite with much granular sphene.

$J_1/440$. *Loc.*—No. 14 on map.

Des.—Pyroxene hornblende granulite. Pyroxene is pale green augite passing into hornblende and occurs between rounded grains of felspar and quartz with granular sphene.

$J_1/441$. *Loc.*—A few yards west of above.

Des.—A veined granular schist containing much more augite than above; also epidote, sphene and pyrites.

$J_1/458$, $J_1/460$. *Loc.*—Edge of schists 1 mile W. S. W. of Kempapur.

Des.—Banded granular schists with numerous sphene grains and some epidote.

$J_1/508$. *Loc.*—Inclusion in granite just west of No. 22 on map.

Des.—Fairly fine hornblende *granulite* with much granular sphene.

$J_1/509$. *Loc.*—No. 22 on map-schist next to granite.

Des.—Same as $J_1/508$, but showing an acid vein containing much pale augite.

This specimen is remarkable, the vein with augite is probably subseqent to the formation of the granulite.

$J_1/511$. *Loc.* —No. 24 on map.

Des.—Hornblende *granulite* with a little pale green augite and granular sphene.

$J_1/512$. *Loc.*—A little S. S. W. of above. A patch in the central granite.

Des.—Similar to $J_1/511$, but coarser in texture and with indefinite bands containing much augite.

Tabular view of Specimens.

In the above specimens it will be noticed that the more granulitic types occur at the borders of the schist or as inclusions in the granites and that on the whole the latter afford the most specimens of typical granulites. Further than this the association of sphene with augite is remarkable and also the fact that ilmenite and augite do not occur together. Ilmenite and sphene occur in the same section but their proportions are more or less inversely proportional. For the sake of exhibiting more clearly the association of the various minerals in the specimens described, not only in this section but also in the previous sections, I append the following tabular statement of all the specimens described with their essential minerals. Where the latter occur in normal proportions or in fair quantity. They are indicated by the letter + and where they occur in small or, much less than normal quantities, they are indicated by the letter *x*. A few remarks are also added showing the situation of the specimen with regard to the schist belt and surrounding granites and indicating the rearness of approach to granulitic types. A rough analysis of the table shows the following relations amongst the constituent minerals.

Practically all of the specimens contain hornblende and felspar the quantities of which may vary widely from those shown by the unaltered schists according to the amount of alteration and the proportions of the secondary minerals present. The unaltered schists (No. 1) as judged from many hundreds of sections contain only hornblende, felspar and ilmenite with traces of other minerals which need not be noticed. No. 28 is also practically unaltered schist.

The remaining 83 specimens are considered to be altered or modified schists and of these 11 show only hornblende, felspar and ilmenite and 1 shows in addition a little

epidote. All of these 12 specimens are more or less granulitic and occur close to or in granite. Of the remaining 71 specimens all except two contain quartz in appreciable quantities and 59 of them contain sphene.

Of the above 71 specimens, 47 (of which two are doubtful) contain augite and of these all except 1 contain quartz and all except 3 contain sphene while none of those with augite contain ilmenite except as small specks in granules of sphene.

The presence of quartz sphene and augite and the absence of ilmenite are therefore very characteristic of the altered schists as is to a lesser degree the presence of pyrites, epidote, calcite, mica, garnet and apatite as shown by the table.

Tabular View of Com-

Serial No.	No. of Specimen.	Hornblende.	Felspar.	Ilmenite.	Quartz.	Sphene.	Augite.	Pyrites.	Epidote.
					General Type of Un-				
1		+	+	+					
					Altered				
					(A). Associated with Con-				
2	J_1/488	x	+		+	+	+		
3	J_1/154	x	+		+	+	+		
4	J_1/198	+	+	x	+	x	+		
5	J_1/292	x			+	+	+		
6	J_1/463		+		+		+	+	+
7	J_1/346	+	+		+	+	+		
8	J_1/372	+	+		+	+	+	+	
9	J_1/499	+	+		+	+	+		+
10	J_1/515	+	+		+	+	+	+	
11	J_1/517	+	+		+	+	+		+
12	J_1/541	+	+		+	+	+		+
13	J_1/570	+	+		+	+	+	+	+
14	J_1/576	+	+		x	+	+		
15	J_1/583	+			+	+	x		+
16	J_1/584	+			+	+	+		+
					(B) Specimens from				
17	J_1/79 J_1/906 S_2/47	+	+		+		+	+	

position of Specimens.

Calcite.	Mica.	Garnet.	Apatite.	Locality.	Remarks.
altered Schist.					
				Main mass of the schists	Texture diabasic to basaltic or homogeneous schists.
Schists.					
glomerate Series (C.S.)					
				Inclusion in C.S.	Granulitic.
				” ”	”
				Close to C.S.	Banded, granular.
	x			” ”	” ”
				” ”	Acid band in Hornblende schist.
x	x			” ”	Banded schist.
				” ”	
				” ”	Veined amphibolite.
				Inclusion in C.S.	Fine banded schist.
				” ”	Granulitic.
+				Close to C.S.	
				” ”	Banded, partly granulitic.
+				Inclusion in C.S.	Banded schist.
+	+			Tongue in C.S.	Granular schist.
+	+			” ”	” much mica.
Body of Schists.					
+					Schist with eyes or knots of acid material.

Tabular View of Com-

Serial No.	No. of Specimen.	Hornblende.	Felspar.	Ilmenite.	Quartz.	Sphene.	Augite.	Pyrites.	Epidote.
18	$J_1/218$	+	+		+	+	+		
19	$J_1/269$	+	x		+	+	+		
20	$J_2/5$	+	+	x	+	+	+	+	
21	$J_1/505$	+	+		+	+	+		
22	$J_1/507$	+	+		+	+	+		
23	$J_1/387$	+	+		x		+	x	
24	$J_1/538$	+	+		+	+	+	+	
						Specimens from the			
25	S/39	+	+	x	+	x		x	
26	S/40	x	x		+	+	+	+	
27	S/41	+	x	x	+	+		x	
28	S/42	+	+	+					
29	S/63*a*	+	+		x	+		+	+
30	S/63*b*	x	x		x	+	+	+	+
31	S/63*c*	x			+	+	+	+	+
32	S/64	+	+		+	x	+	x	+
33	S/93	+					+	+	
34	S/97	+			+			+	+
35	S/98	+						+	
36	S/101	+	x	+	+			+	

position of Specimens—(*Continued.*)

Calcite.	Mica.	Garnet.	Apatite.	Locality.	REMARKS.
					Fine veined schist.
	x				Schist with quartz veins.
+					Veined schist, granular.
					" "
			+		" "
+					" "
					" "
Quartz Reefs.					
				Ooregum Mine.	Footwall of lode.
+	(*Series*)			" "	Lode matter.
				" "	Hanging wall of lode.
				" "	Schist 20 ft. west of lode.
	x			" "	Hornblende schist band in lode.
		(*Series*)		" "	Augite band in lode.
+				" "	Quartz band in lode.
+		+		" "	Schist veined with quartz; contains also Tourmaline and Topaz.
+	+	+		Nundydroog Mine	Banded amphibolite; footwall of lode.
+				Champion Reef Mine.	Schist breccia in lode.
	+			Ooregum Mine Hanging wall.	Amphibolite veined with actinolite.
	+			Ooregum Mine	Amphibolite with quartz veins containing Tourmaline and Mica.

Tabular View of Com-

Serial No.	No. of Specimen.	Hornblende.	Felspar.	Ilmenite.	Quartz.	Sphene.	Augite.	Pyrites.	Epidote.
									Granulitic
								(*a*).	*Specimen from*
37	$J_1/194$	+	+	+					
						(*b*).	*Series showing*		*progressive*
38	$S_2/32$	+	+	+					
39	$S_2/33$	+	+	+					
40	$S_2/34$	+	+	+					
41	$S_2/36$	+	+	+	x				
						(*c*).	*Types in*	*and close to*	
42	$J_2/8$	x	+		+	x	+		
43	$J_2/9$	+			+				
44	$J_1/967$	+	+	x	?	+	+	x	
45	$J_1/968$	+	+	x	+	+	?		+
46	$J_1/969$	+	+	x	+	+	?		+
47	$J_1/974$	x	+		+	+	+	+	+
48	$J_1/976$	+	+	x	+				
49	$J_1/979$	+	+		+	+	+		
50	$J_1/985$	+	+	x	+				+
						(*d*).	*Specimens from*		*South*
51	$J_1/535$	+	+		x	+		+	+
52	$J_1/553$	+	+		x	+			

position of Specimens—*(Continued.)*

Calcite.	Mica.	Garnet.	Apatite.	Locality.	Remarks.
Types.					
body of schists.					
					Granulitic schist.
development of granulitic texture.					
				100 yds. E. of W. granite.	Fine granular schist.
				50 yards W. of above.	Coarser granular schist.
				50 yards W. of above next to granite.	Granulitic schist.
				Band in granite.	Coarser granulitic schist.
Western granites and gneisses.					
				Close to granite.	Granulitic schist.
		+		E. of above, near Hæmatite Quartzite.	Very granular schist.
				Inclusion in granite.	Granulite.
				" " "	"
				Next to granite.	"
				" " "	Fine granular schist.
				Schist near granite.	Granulitic schist.
+				Next to granite.	Fine granular schist.
				Inclusion in granite.	Fine grained granulite.
Western limb of Schist Belt.					
				Close to granite.	Granulite.
				Inclusion in granite.	"

Tabular View of Com-

Serial No.	No. of Specimen.	Hornblende.	Felspar.	Ilmenite.	Quartz.	Sphene.	Augite.	Pyrites.	Epidote.
53	J_1 554	+	+		x	+	+	+	
54	J_1 569	+	+	+					
55	J_1 581	+	+		x	+		+	
56	J_1 582	+	+		+	+			
57	J_1 587	+	+	+	+	+	+		+
58	J_1 588	+	+		+	+	+		+
59	J_1/591	+	+		+	+	+	+	
60	J_1/601	+	+		+	x			
					(e). Specimens from the South				
61	J_1/329	+	+	+					
62	J_1/382	+	+	+					
63	J_1/344	+	+		x	+			
64	J_1/345	+	+		x	+			
65	J_1/347	+	+	+					
66	J_1/348	+	+	+					
67	J_1/354	+	+	x					
68	J_1/355	+	+	+					
69	J_1/361	+	+	+					+
70	J_1/362	+	+		+	+			

position of Specimens—*(Continued.)*

Calcite.	Mica.	Garnet.	Apatite.	Locality.	REMARKS.
				Inclusion in granite.	Granulite.
				Close to granite.	Very granular schist.
+				" "	Banded granular schist.
				Inclusion in granite.	Granulite.
		+		Near granite.	Veined amphibolites, granulite in parts. Iron one is restricted to veins and does not occur with the augite.
			+	Close to granite.	Granulite.
				" "	Granulitic.
		+		Inclusion in granite.	Granulite.
East limb of the Schist Belt.					
				Close to granite.	Granulitic schist.
				" "	" "
				" "	Granular to granulitic.
+			+	" "	" "
				Near granite.	Granulitic schist.
				" "	" "
				Next to granite.	Squeezed granulite
				" "	Very granulitic.
				Near granite.	" "
				" "	Squeezed granulite.

Tabular View of Com-

Serial No.	No. of Specimen.	Hornblende.	Flespar.	Ilmenite.	Quartz.	Sphene.	Augite.	Pyrites.	Epidote.
71	J_1/364	x	+		x	+	+	+	
72	J_1/366	+	+	x					
73	J_1/386	+	+	x	+	x			
74	J_1/416	+	+		x	+	x		
75	J_1/201	+	+		x	+	x		
76	J_1/422	+	+		x	+	+		
77	J_1/423	+	+			+			
78	J_1/440	x	+		+	+	+		
79	J_1/441	x	x		+	+	+	+	+
80	J_1/458	+	+		x	+			+
81	J_1/460	+	+		x	+			+
82	J_1/508	+	+		+	+			
83	J_1/509	+	+		+	+	+		
84	J_1/511	+	+		+	+	x		
85	J_1/512	+	+		+	+	+		

position of Specimens—*(Continued).*

Calcite.	Mica.	Garnet	Apatite.	Locality.	Remarks.
				Next to granite.	Pyroxene granulite.
				Near granite.	Granulite.
				" "	Granulitic schist.
				Inclusion in granite.	Coarse granulite.
				" "	Granular Diorite.
				Band in gneiss.	Coarse granulite.
				Near granite.	Fine granulite.
				Close to granite.	Pyroxene Hornblende granulite.
				" "	Veined granular schist.
				Next to granite.	Banded granular schist.
				" "	" " "
				Inclusion in granite.	Granulite.
				Next to granite.	"
				" "	"
				Inclusion in granite.	"

V.—SUMMARY.

In the present paper my chief object has been to draw attention to the occurrence of augite in the Kolar schists and I have endeavoured to show that the augite is a secondary mineral developed in hornblende schist in proximity to, and as the result of intrusion of acid material into the schists. The general line of argument has been as follows:—

The hornblendic schists of the Kolar Belt are essentially the metamorphic representatives of an ancient series of basic lava flows which in all probability originally consisted of the minerals augite, plagioclase and ilmenite. Metamorphism has resulted in the complete conversion of any original augite into bluish green hornblende so that the schists now consist of hornblende, plagioclase and ilmenite. In many cases the original igneous texture of the lava flows is still clearly apparent in the schists but in other cases severe crushing and shearing has defaced any original texture and the minerals have been much broken up and sometimes recrystallized. In both cases however the component minerals appear to be similar and the various beds of schist remain as homogeneous masses of rock in which no augite whatever has been detected. Locally however the schists are irregularly veined with acid material and near the edges of the belt, in proximity to granites and gneisses which I believe to be intrusive with regard to the schists, the schists are sometimes found to be banded as well as veined. The banding is parallel to the planes of schistosity and the bands are lighter in colour and more acid in composition than the normal schist. There can be no

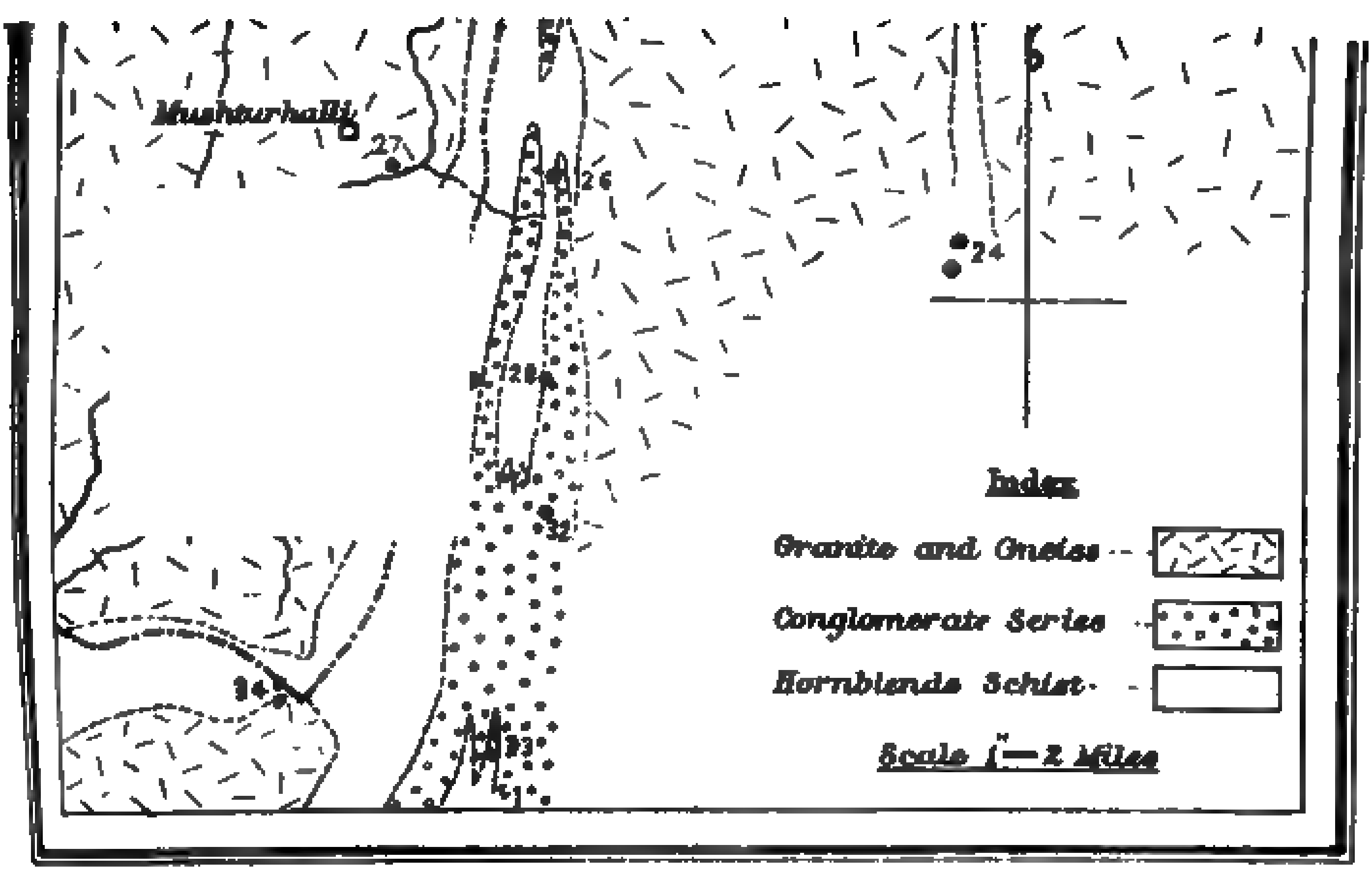
doubt that the irregular or cross veins of acid material are secondary features introduced into the schists but there might be some doubt as to whether the banding is original or secondary although I myself am satisfied that it is secondary.

Augite is a common mineral is these veined and banded schists as well as in patches of schist which occur as inclusions in the granite and gneiss and the very marked association of the mineral with secondary acid veins is sufficient to prove that it is itself of secondary origin. Its occurrence in the banded schists is also quite in accordance with this view and strongly supports the contention that the banding of the schists is of secondary origin due to the intrusion of more or less parallel sills of acid material. These views are further supported by other mineral charges which accompany the formation of augite in and about the acid veins and bands and in the fragments of schists included in the surrounding granites and gneisses. These changes include the constant alteration of the ilmenite of the schists to sphene and the frequent development or introduction of some or all of the following minerals, *viz.*, pyrites, calcite, epidote, mica, garnet, apatite, tourmaline and topaz in addition to the quartz and felspar forming the veins and bands.

The secondary augite exhibits the usual tendency of this mineral to revert to hornblende and it is noteworthy that the resulting secondary hornblende bears a very strong family likeness to the original hornblende of the schists so much so that it is as a rule impossible to distinguished between them.

Part II of the paper deals with the occurrence of similar augite in association with the auriferous quartz veins of the Kolar Gold Field. These veins are sometimes thick and solid and sometimes break up into numerous thin stringers forming a finely banded schist not unlike the banded schist referred to in Part I save that the acid

which they are associated. There is abundance of material for such study in many parts of Mysore and I think I have said enough in the body of this paper to suggest several lines of investigation which may lead to useful results. The development of secondary augite in hornblende schist in the neighbourhood of acid veins and the development of granulitic textures, with or without augite, under the influence of masses of intrusive granite or gneiss are not to my mind mere petrological curiosities but are features of widespread occurrence which are likely to prove of importance in reconstructing the early geological history not only of Mysore but of a large area of peninsular India. In conclusion I regret the incompleteness of much of the evidence referred to in the paper and the absence of figures or sketches illustrating the principal petrological types which have been described; I may be able to amend this later by publishing a series of plates separately. I also wish to acknowledge the assistance I have received from Mr. B. Jayaram, Assistant Geologist, by whom many of the specimens which I have described were collected during survey work on the Kolar Belt as well as many specimens of similar import from other parts of the State.



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MYSORE GEOLOGICAL DEPARTMENT.

BULLETIN
No. 4.

ROCK DENSITIES

in the neighbourhood of

EDGAR'S SHAFT, MYSORE MINE,

KOLAR GOLD FIELD.

BY

W. F. SMEETH, M.A., D.SC.,

State Geologist and Chief Inspector of Mines.

MADRAS:

PRINTED BY HIGGINBOTHAM & CO.

1908.

Price—One Rupee.

ROCK DENSITIES IN THE NEIGHBOURHOOD OF EDGAR'S SHAFT, MYSORE MINE, KOLAR GOLD FIELD.

The following notes were compiled in response to a request from Major Lenox Conyngham, R.E., Superintendent of the Survey of India, for some information as to the densities of the rocks in the neighbourhood of Edgar's Shaft on the Kolar Gold Field. Major Conyngham visited the Kolar Field in February 1908 for the purpose of making some observations on the intensity of the force of gravity in connection with a series of similar observations throughout India. It was decided to determine the value of *gravity* not only at the surface but also, if possible, at some considerable depth below ground, and for this purpose Edgar's Shaft was found to be particularly suitable.

This shaft is vertical, circular in section, lined throughout with brick and has recently been completed to a depth of about 2,600 feet. At the time when the experiments were made the shaft was devoid of all internal fittings and no work was being carried on in it. It represented simply a large circular hole in the rocks to a depth of 2,600 feet situated at a considerable distance from the other underground workings of the mine and was singularly adapted to the purpose of the observations contemplated.

The results of the observations on the value of *gravity* will doubtless be announced in due course and in the meantime the following notes on the nature and densities of the rocks in the neighbourhood of the shaft are published as they may be of some general interest.

The general surface distribution of the rocks in the neighbourhood of Edgar's Shaft is shown on Plate I. The position of the shaft is shown by a small circle and a cross section of the country along a line passing east and west through the shaft is represented in Plate II.

Geology.

The Kolar Schist belt is composed of a series of hornblendic rocks stretching north and south and bounded on the east and west by granitic rocks.

The main mass of the schist belt is composed of ancient basic lava flows which have been folded by east and west movements so that the originally horizontal beds (flows) are now steeply inclined. On the eastern side of the schist belt the beds dip to the west at an angle of about 50° and on the western side of the belt they mostly dip to the east at very high angles, being in some cases vertical. The general lie of these rocks is indicated by shading on Plate II.

On the east side of the main mass of the belt is a wide band of granitic material forming the "conglomerate series." This series is largely composed of granite and gneiss and contains bands and patches of the hornblendic rocks. It is probably intrusive into the hornblende schists, but it contains numerous rounded lumps or pebbles and was at one time regarded as a conglomerate.

On the east of the conglomerate series is a long narrow band of hornblende schist and to the east of this stretches a wide expanse of gneissic granite extending for many miles. On the west of the main mass of the schists there is likewise a wide expanse of gneissic granite.

The hornblendic rocks were most probably lava flows composed of pyroxene and felspar, but owing to

metamorphic changes the pyroxene has completely altered into bluish-green hornblende and the existing rocks are composed essentially of this hornblende with felspar and a little ilmenite. Local subsidiary changes have given rise to quartz, calcite, mica and sphene in comparatively small quantities. The texture of the rocks varies considerably in different beds, but their chemical composition is very fairly uniform. Signs of considerable crushing are evident in many of the beds or layers which now possess a schistose structure and the whole series of hornblendic rocks may be classed as "hornblende schists" or "epidiorite."

These hornblende schists occupy a more or less trough-like depression in the surrounding granitic rocks, but the structure of the belt does not seem to be that of a simple synclinal fold but rather a portion of a syncline more or less distorted and broken up by the intrusive granites. The section (Plate II) does not pretend to represent the actual shape of the lower boundary of the schists, which is doubtless very irregular, but merely gives the probable average distribution of the various rocks represented in relation to the depth and position of Edgar's Shaft. The shaft is practically half a mile in depth and is not far from the middle of the main mass of the schist and the latter probably extends downwards for well over a mile below the bottom of the shaft.

Specific Gravity of the Conglomerate Series.

The conglomerate series is a very complex one and no direct determination of the specific gravity is possible, but from various samples and a knowledge of the general character of the complex the specific gravity may be estimated at about 2·68.

Specific Gravity of the eastern and western gneissic granite.

The gneissic granites are also very complex, but it will probably be fairly correct to take the specific gravity at 2·66.

Specific Gravity of the Hornblende Schists.

For the purpose of the Pendulum observations, the specific gravity of the hornblende schists which so largely surround the point of observation is of the chief importance and fortunately a number of actual samples of the rocks met with in Edgar's Shaft have been preserved and their specific gravity determined. A similar series has also been determined for Bullen's Shaft which is situated about a mile and a half north of Edgar's Shaft.

These observations enable the densities at these points to be very closely determined and the same results may be extended to the whole mass of the hornblende schists without appreciable error.

The following table gives the specific gravity of the specimens taken at the depths mentioned from the two shafts:—

TABLE A.

Edgar's Shaft.			Bullen's Shaft.		
Serial No.	Depth in feet.	Sp. Gr.	Serial No	Depth in feet.	Sp. Gr.
1	668	3·18	1	100	2·90
2	692	2 96	2	200	3·00
3	737	2·98	3	300	2·96
4	749	3·15	4	400	2·99
5	764	2·98	5	500	3·03
6	767	2·96	6	600	3·05
7	803	3·04	7	700	3·01
8	813	3·03	8	800	3·03
9	838	2·90	9	900	3·03
10	850	2·98	10	1000	2·96
11	883	2·96	11	1100	3·01
12	1000	3·00	12	1200	2·96
13	1100	2 98	13	1300	3·00
14	1200	2·93	14	1400	3·01
15	1300	3·10	15	1500	3 01
16	1500	2·96	16	1600	3.05
17	1600	2 93	17	1700	3 04
18	1700	3·05	18	1800	3·05
19	1900	3·00	19	1900	2·99
20	2000	3·02	20	2000	306
21	2100	3·03	21	2100	3·14
22	2200	3·02	22	2200	3·01
23	2300	3·02	23	2300	3·07
24	2400	3·00	24	2400	3·06
25	2500	3·05	25	2500	3·03
26	2600	3·14	26	2600	3·00
27	...	...	27	2700	3·04
28	...	...	28	2800	3·00
29	...	...	29	2900	2·97
Average	...	3·013	Average	...	3·016

The foregoing table shows that the hornblendic rocks in which these shafts have been sunk are very uniform as regards specific gravity. The average results for the two shafts are the same within the limits of error of the determinations and the maximum variation does not exceed 5 per cent. of the average value.

Before accepting these average values there are a few points which require consideration. These are:—

(1) Depth to which weathering has affected the rocks and the effect on the specific gravity.

(2) Extent of the zone of permanent water saturation and its effect on density.

(3) Amount of moisture in the specimens referred to in the above list and in the rocks as they occur in the ground.

(4) Allowance for alterations and replacements of the rocks by other minerals.

(1) *Weathering.*—The rocks are usually considerably altered down to a depth of from 50 to 100 feet, the alteration being greatest at surface and gradually diminishing with depth down to about the point at which the permanent water level is found. The decomposition of the rock is due to its being alternately saturated with surface waters and then dried and saturated with air. Some samples from the weathered zone which were examined gave the following results.—

1st 10 feet	Sp. Gr.	1·65
At 20 ,,	,,	2·64
,, 30 ,,	,,	2·66
,, 40 ,,	,,	2·71
,, 50 ,,	,,	2.82
,, 100 ,,	,,	2·90

The determination of the specific gravity of the more decomposed specimens presented some difficulty owing to

the fact that as soon as the specimens were placed in water they fell to pieces producing a sludge at the bottom of the vessel. For the purpose required the determination of the specific gravity of the powdered or broken up rock would be useless as what is required is the density of the rock mass as a whole including the porous parts or air space. In order to arrive at an approximate value, the specimens were coated with varnish which was allowed to dry and this had the desired effect of keeping the specimen from crumbling and preventing the escape of air for a sufficiently long time to enable the weight in water to be determined. The figure 1·65 as thus determined for the more decomposed rock near the surface is probably not far from the truth, but it must be remembered that even in the highly decomposed zone there are harder and heavier portions which are less weathered. In fact the first 10 or 20 feet from surface is unquestionably the most variable as regards density and in endeavouring to fix an average value it would probably be fair to assume it to be about 2.

Assuming this to be correct and that the average density of each descending layer taken over a large area increases regularly and continuously for the first 100 feet, we may with the aid of the abovementioned figures draw a curve which will give the following results:—

At	surface,	density	= 2·0
„	10 feet	„	= 2·3
„	20 „	„	= 2·5
„	30 „	„	= 2·64
„	40 „	„	= 2·75
„	50 „	„	= 2·82
„	100 „	„	= 2·90

These figures may be assumed to be fairly correct and probably more trustworthy than actual determinations derived from a limited number of samples.

(2) *Zone of permanent water saturation.*—The permanent water level, unless locally disturbed, is usually found between 50 and 100 feet from the surface and it extends downwards to from 250 to 300 feet from surface. In other words, between these levels the rock is permanently saturated with water; above the upper level the rock becomes saturated after the rains and dries again during the dry season while below the lower level the rock is free from any appreciable quantity of water except along certain fissures or planes of weakness such as those connected with many of the quartz reefs, dykes or cross-courses.

The foregoing remarks apply to the conditions usually found in the schists, but in the case of Edgar's Shaft it is reported that very little water was met with and that only at a depth of about 260 feet from surface. If this was so the water zone at Edgar's Shaft must have been of very limited extent vertically.

It may be worth while to enquire what effect this water has on the density of this zone of wet rock. The first three figures in the table for Bullen's Shaft show that the specific gravity of the rock in this zone is very slightly, if anything, lower than the average specific gravity at lower depths. These figures were however determined on specimens which had been removed from the shaft for some time and were practically dry. They do not represent therefore either the specific gravity of the specimens in situ or the density of the combined rock and water.

To determine the effect of saturation by water four specimens from Bullen's Shaft were weighed, then soaked in water for 24 hours and after allowing the surface to dry re-weighed and their specific gravity determined. The specific gravity of four similar specimens without soaking in water was also determined for comparison.

Results were as follows :—

No. in Table A.	Weight before soaking, gms.	Weight after soaking, gms.	Water absorbed.	Sp. Gr. after soaking.	Sp. Gr. before soaking.
12	44·877	44·882	·005	2·99	2·96
15	24·148	24·155	·007	3·00	3·01
21	28·190	28·195	·005	3·12	3·14
22	38·257	38·272	·015	3·03	3·01

The amount of water absorbed is very small indeed and its effect on the specific gravity also very slight. As the water which is absorbed displaces air, there ought to be in each case a slight increase of specific gravity, but two of the results show a decrease which must be attributed to the fact that the specimens used were not identical but were different fragments from the same sample of rock and also to experimental errors.

Four specimens from Edgar's Shaft were then taken and their specific gravity determined and the same four specimens were subsequently soaked in water for 24 hours and their specific gravity again determined with the following results :

No. in Table A.	Sp. Gr. before soaking.	Sp. Gr. after soaking.
1	3·18	3·18
9	2·90	2·98
20	3·02	3·03
26	3·14	3·16

From these results we see that saturation with water increases the specific gravity, but only to a very slight extent.

It must be noted however that all of the above specimens are taken from below the water zone and that there might be a greater absorption of water in specimens from that zone. No such specimens are available from Edgar's Shaft, but the first three specimens (Table A) from Bullen's Shaft may be taken as representative. The specific gravity of these was therefore determined after soaking in water with the following results:

No. in Table A.	Depth from surface. Feet.	Sp. Gr. of dry specimens.	Sp. Gr. after soaking in water.
1	100	2·90	2 96
2	200	3·01	3·01
3	300	2·96	2·97

No. 1 is distinctly a more altered rock than the others and the increase in its specific gravity is marked as might be expected.

The average specific gravity of these three specimens after soaking in water is 2·98.

The quantity of water which is absorbed by the rock is so small that it cannot form the source of the free water which is met with in sinking through the water zone and the latter must therefore occur essentially in joints and cracks in the rock. This means that the density of the rock in this zone must be less than that of the specimens above determined owing to the presence of these joints and cracks filled with water. If we assume

that such joints and cracks amount in value of one per cent. of the mass, we would have 99 parts wet rock weighing 2·95 and one part of water weighing ·01, giving a combined density for the mass of rock and water of 2·96. This is an approximation in the right direction and in default of more accurate data may be adopted.

(3) *Moisture.*—Below the permanent water zone the rocks of the schist belt are found to be practically dry, that is to say, when excavations are made therein no water exudes from the rock and the surfaces of the excavation remain to all appearance dry except in a few cases where a plane of weakness in the rock happens to be intersected and permits the percolation downwards of water from the permanent water zone. Taken as a whole, the rocks below this zone may be regarded as dry. On the other hand there is no doubt that they contain some absorbed water the amount of which might be appreciably different from that contained in the specimens, referred to in Table A, which had been removed from the shafts and exposed to the air for considerable periods. In order to obtain some information on this point two specimens A and B were obtained from underground from two fresh excavations, the specimens being freshly broken out and immediately sealed in jars.

A was taken from a crosscut West, 28th level, Champion Reef.

B was taken from the bottom of Bullen's Shaft at a depth of 2,930 feet.

The specific gravity of each specimen was then taken and the amount of moisture present determined with the following results:—

A	Specific gravity	3·12	moisture	0·07	per cent.
B	„	3·10	„	0·11	„

For comparison with these the moisture in following four specimens of Table A from Edgar's was determined :—

Serial No.	Specific Gravity.	Moisture.
1	3·18	0·11 per cent
9	2·90	0·10 ,,
20	3·02	0·107 ,,
26	3·14	0·19 ,,

It is obvious that both in the fresh specimens A and in the old specimens of Table A the amount moisture present is very small and very similar and ther that the actual specific gravities are as nearly as be expected the same in the two cases.

We may therefore regard the specific gravities g in Table A as fairly representing the fresh rocks in

(4) *Influence of alterations and replacements.*— bottom of Edgar's Shaft where the pendulum observa were made is 2,626 feet below the surface. At 2,370 a quartz reef 4 feet wide cuts across the shaft at an a of 50° and at 2,405 feet another quartz reef 3 feet similarly crosses the shaft. In addition to these b numerous small stringers, gashes and headings of qu and calcite occur throughout the mass of the schists these all tend to lower the average density of the sch It is difficult to estimate the amount and influenc these lighter portions, but it is very probable that the not exceed one per cent. of the whole mass and are very far short of this figure and we may assume

per cent. to be correct for purposes of calculation in default of more exact data. From Table A we get 3·0145 as the average density of the hornblendic rock which forms 99 per cent. of the whole mass and the remaining one per cent. is composed of quartz with a little calcite the average density of which may be taken at 2·6. A unit mass will therefore be composed of 99 parts weighing 2·9843 and of 1 part weighing 0·026, the sum of which figures gives 3·0103 as average density of the aggregate, which is probably as close an approximation as can be obtained with the data to hand.

Correction for Temperature.

It will be unnecessary to introduce any temperature correction for the specimens from the first 300 feet in depth as the figures already deduced can be regarded as only very approximate and the influence of any small change in the density of this layer would be inappreciable. For the constant density of 3·0103 which has been obtained for the rock below the 300 feet level it seems worth while to introduce the temperature correction as a further approximation.

The average temperature of the water in which the specific gravity determinations were made was about 28° C. and the specific gravity of water at this temperature is 0·9963 referred to water at 4° C. as density.

The average density of the rock referred to water at 4° C. as unity will therefore be

$3{\cdot}0103 \times 0{\cdot}9963 = 2{\cdot}999$ and the final result may be taken as 3·00.

Summary.

The results which have been obtained go to show that for the mass of the hornblende schists comprising the Kolar Belt the density increases from surface downwards according to

the following scale :—

At surface,	density	= 2·00
„ 10 ft.	„	= 2·30
„ 20 „	„	= 2·50
„ 30 „	„	= 2·64
„ 40 „	„	= 2·75
„ 50 „	„	= 2·82
„ 100 „	„	= 2·90
„ 200 „	„	= 2·96
„ 300 „	„	= 3·00

and that below 300 feet the density remains on the average constant at 3·00.

The results can, from the nature of the case, be regarded only as approximate and the introduction of a number of small corrections does not imply that the figures are considered to be accurate within the limits of those corrections. The average of the determinations given in Table A was 3·0145 and the value as finally corrected is 3·00 and the difference between these two values is certainly within the limits of experimental error. On the other hand a discussion of the various corrections to be applied has shown that they are all minute and cannot influence to any great extent the results determined from a fairly representative series of specimens.

On Plate III a transverse section through Edgar's Shaft is shown, the materials for which have been kindly supplied by the Superintendent of the Mysore Gold Mining Company, and alongside this is given a diagram showing the average values of the density from surface downwards as deduced in the foregoing notes.

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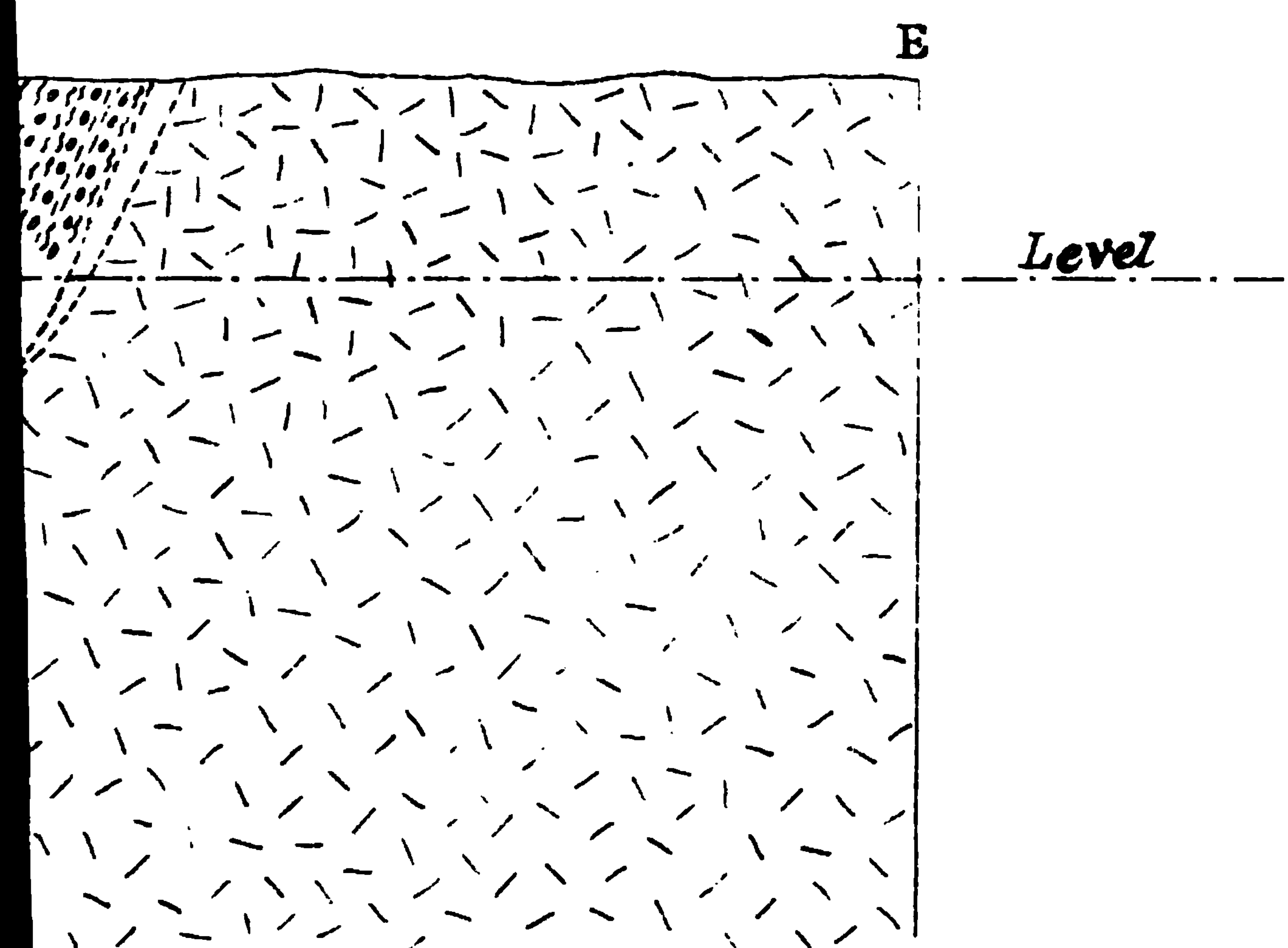
Bulletin No. 4

Plate I

Plate II.



Index

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nglomerates (Chiefly Granite)

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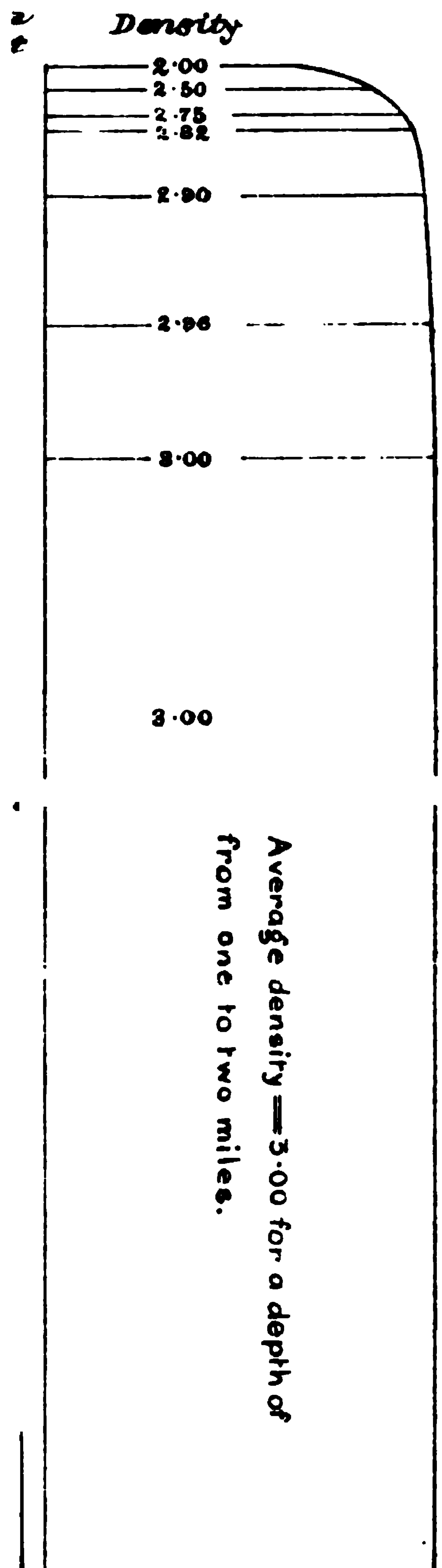
rrugineous Quartz Schist

Plate III

DIAGRAM OF

density of the Schist



MYSORE GEOLOGICAL DEPARTMENT.

BULLETIN

No. 5.

NOTES ON THE ELECTRIC SMELTING

OF

IRON AND STEEL

BY

W. F. SMEETH, M.A., D.Sc.,

State Geologist and Chief Inspector of Mines.

BANGALORE:
PRINTED AT THE GOVERNMENT PRESS
1909.

4/6
PRICE ~~TWO RUPEES~~.

Dept. of mines and geology

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CONTENTS.

PART I.—SMELTING OF SCRAP AND ORE.

PART II.—MATERIALS AND COSTS IN MYSORE.

NOTES ON ELECTRIC SMELTING OF IRON AND STEEL.

BY W. F. SMEETH, M.A., D.Sc.,
State Geologist and Chief Inspector of Mines in Mysore.

THESE notes embody the technical portions of a report prepared by me at the request of the Government of His Highness the Maharaja of Mysore and are the outcome partly of some experiments made with the Stassano furnace at Turin in January 1908 and partly of a study of various other processes for the Electrothermal treatment of iron and steel which have been tried or operated during the past ten years or so.

As the notes may be of some interest to others who are working in these subjects, I have obtained permission to publish them in their present form.

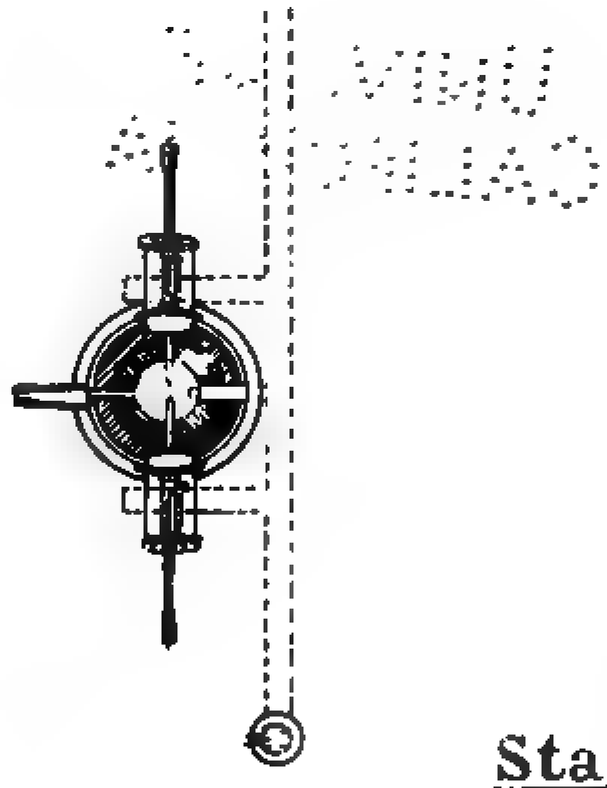
At the request of Major Stassano I paid a visit to his works at Turin in November 1907 for the purpose of witnessing some trials for the reduction of iron ore in an electric furnace of 1,000 h.p. Owing to a strike of workmen at Turin, the furnace was not ready for work when I arrived, and subsequently the necessary power to run the furnace could not be obtained, as during the winter months the entire output of the Electric Power Company, from which the current was to have been obtained, was required for lighting and other purposes in the town of Turin.

I was unable therefore to witness the particular trials which I had gone to Turin to see, but Major Stassano

Bulletin No. 5

Fig. 1

100 H.P.



Sectio

Stassano

Scal

Fig. 2

200

Plate II

Fig. 3

1000

ns of

Furnaces

$\frac{1}{100}$

Fig

1000

The electrodes are carbon rods attached to steel pistons which travel in water-jacketed cylinders attached to the shell of the furnace; the pistons with their carbons are moved towards and away from the centre of the furnace by small hydraulic rams, the valves to which are worked by hand at the operating table which is situated some distance from the furnace in view of the voltmeter and ammeters.

Plate II shows sections of the various furnaces erected at the Forni Termoelecttrico Stassano at Turin drawn to a scale of $\frac{1}{100}$.

The small furnace of 100 h.p. (Fig. 1) is fixed and has two electrodes carrying monophase alternating current at 70 volts and 1,000 amperes.

Fig. 2 represents either the rotating or the oscillating furnace of 200 h.p. There are three electrodes supplied with three-phase alternating current. In the oscillating furnace, which was the one used for the experiments with iron ore, the voltage was 150 and the current normally 700 amperes. In the revolving furnace the voltage was rather lower and the current higher.

Three arcs are formed between the points of the 3 carbons at a short distance above the charge on the hearth.

In the oscillating furnace there is of course no revolving gear or brushes below the furnace which is hung on trunnions and can be slowly rocked. The slag when sufficiently fluid, as was the case in the ore experiments, can be poured off through the tap hole by tilting the furnace

Fig. 3 is a section of a fixed furnace of 1,000 h.p. with three pairs of electrodes supplied with three-phase current. The three arcs which are formed are distributed over a considerable area and give a better distribution of heat over the charge. This furnace was not in commission at the time of my visit.

Fig. 4 is a section of the new revolving furnace of 1,000 h.p. in which there are also three pairs of electrodes

giving three arcs distributed round the circumference of a circle of some 3 to 4 feet in diameter. This allows of the possibility of dropping the briquettes from the top opening on to the hearth without damaging the carbons or short-circuiting the arcs.

On the whole, the furnace performs its function of furnishing a practically closed chamber with an internal source of heat very well. The adjustment and replacement of electrodes are simple matters and the arcs are easily controlled. The carbons do not come in contact with the charge and the arcs remain steady except just after fresh material is charged when the gases evolved make them rather jumpy.

The lining is a rather expensive and troublesome item and tends to break away. A little patching can be effected through the side door, but on the whole this is the least satisfactory part of the arrangement and may possibly be improved with further experience.

On the whole the furnace appeared to me to be a very satisfactory contrivance and particularly suitable for experimental work with various kinds of material and for various classes of operation.

II.—PRODUCTION OF STEEL FROM SCRAP IN THE STASSANO FURNACE.

For several years past a Stassano furnace of the revolving type of about 200 h.p. capacity has been at work at the Government ordnance works at Turin and appears to have been giving every satisfaction. The furnace is employed in the melting up of various kinds of workshop scrap and the production therefrom of steel for the manufacture of shot.

The furnace has three electrodes which are supplied with a three-phase current at about 80 volts.

The usual charge is about 600 Kg. of scrap with a little iron ore and limestone.

The charges vary in composition between the following extremes :—

Cast iron scrap	...	150 to 300 Kg.
Iron and steel scrap	...	450 to 300 „
Ore ...	...	29 to 64 „
Limestone	...	6 to 12 „

The furnace turns out an average of 2,500 Kg. of steel per 24 hours in 4 heats. The difference in weight between the scrap charged and the steel produced amounts to a loss of 2 per cent, a very low figure in view of the fact that over two-thirds of the scrap is usually in the form of turnings. If, however, we calculate the total weight of iron in the charge (including ore) and the weight of iron in the steel produced, the loss on the operation amounts to about 4½ per cent, which is still a low figure.

The consumption of energy for each charge of 600 Kg. is about 850 K. W. hours measured on the primary transformer, which, taking into account the losses in the transformer and secondary conductors, gives a consumption of 772 K. W. hours or say 1,300 K. W. hours per metric ton of steel.*

This is a higher figure than some which I shall have occasion to refer to later both for the Stassano furnace and for other furnaces; but it is important to note that the furnace is not a very large one and that a considerable portion of the charge consists of cast iron which requires the addition of iron ore to decarburize it, thereby increasing the quantity of heat required and lengthening the operation.

As the result of work extending over a considerable period at his own works at Turin, Major Stassano has

* Throughout these notes the metric ton will be used. One metric ton=2,204·62 lb.

furnished me with the following figures as to consumption of energy for the production of steel from steel scrap to which a small quantity of pig iron is added for deoxidizing rust:—

100 h.p. furnace	...	2,400 K. W. hours per ton of steel
200 " "	...	1,400 " "
1,000 " "	...	800 " "

These figures, however, include stops and experiments as well as lighting and would be reduced in regular systematic work; but they show the marked advantage due to increase of capacity.

During my visit to Turin I watched either completely or partially a large number of charges being put through the 200 h.p. revolving furnace and through the 200 h.p. tilting furnace and of some of these I will now give particulars.

I may say that in no case did I see any hitch or difficulty about the progress of the operation, or at any rate nothing more serious than the occasional breaking of an electrode, which, if broken off too short for further work, was easily and rapidly replaced without interrupting the work of the furnace, as a single arc continues to be maintained between the other two electrodes.

In the following tables the weight and composition of each charge is given, the components being stated in the order in which they are charged. It will be noticed that the pig iron is charged in two portions. The time at which charging commenced and at which the metal was tapped is also shown.

Date		.08	10—1—08	10—1—08	11—1—08
No. o		6	337	339	...
Charge	F	5	45	45	45
	L	0	200	200	200
	L	0	150	150	150
	F	0	400	400	400
	F	5	25	25	25
	T	0	820	820	820
Additions	O	5	5	5	5
	F	1	1	1	1
	F	3	4'3	4'3	4'3
	A	1	1	1	1
Alumi		2	0'15	...	...
Time		0	11—15	18—0	1—30
Time		5	17—30	1—0	9—45
Durat		5	6—15	7—0	8—15

Before analysing the figures in the foregoing tables it will be desirable to make a few general remarks.

Table A gives the record of eight successive charges in the revolving furnace; but this succession is particularly interesting as it embraces the period of relining of the furnace.

Charge No. 283 on the 2nd January 1908 was the final charge with the old lining which had been in use for the greater part of the previous month. Owing to the wearing away of the lining, the capacity of the furnace tends continually to increase with consequent prolongation of the smelting and refining operation. Thus it will be seen that charge No. 283 on the 2nd January 1908 weighed 1,030 Kgs. and occupied 15 hours, while the charges immediately after relining weighed 820 Kgs. and occupied from 6½ to 10¾ hours.

The relining took a little over 6 days, but I have no doubt from my observations of the work that this period could easily be reduced to 5 days and most probably to 4 days. For relining a larger furnace of say 1,000 h.p. I should think that from 6 to 7 days would be required.

The lining of a 200 h.p. furnace lasts on an average 22 days, and if we allow between 4 and 5 days for relining, we may reckon the time lost at about ⅙ taken over an extended period such as a year. In other words, out of 365 days, 61 would be occupied in relining, leaving roughly a clear 300 working days. Whether this would be more or less with the 1,000 h.p. furnace, I am unable to say.

In order to arrive at an estimate of the time required per charge and per ton of steel produced, it may be noted that the time for charge 283 (Table A) is for some reason exceptionally long even for a large charge. Also, the time for charge 328 is exceptionally long owing to its being the first charge after relining and the furnace not being at full heat. It would be fair, therefore, to omit these two figures and take only the next six charges as

representing the average work of the furnace at this stage. These last six charges have a total weight of 4,920 Kgs., and were in the furnace for a total period of 43 hours, 30 minutes. The current, however, is not on for the whole of this period, being cut off for about an hour during each charge during skimming of the slag. This reduces the total time by 6 hours to 37½ hours.

On the total charge or 4,920 Kgs., there will probably be a loss of about five per cent, say 245 Kgs., making a total product of 4,675 Kgs., for 37·5 hours of current.

This gives approximately *8 hours of current per ton of steel.*

Passing now to Table B, it may be noted that the charges are not consecutive. This is partly owing to the fact that various other experiments were made in between the charges of scrap steel and also because I have not considered it necessary to enumerate all the charges which were put through during my visit. They all run much about the same, but to avoid partiality I have taken one charge for each day and as far as possible I have taken the charge run during the night and which I myself saw finished and tapped in the morning. If anything, this selection must be considered disadvantageous to the furnace as the men on night shift are hardly likely to be so keen and attentive to work as those on day shift, who are also more subject to supervision.

It is to be noted that the charges in Table B were made during the latter portion of the run of the furnace, that is to say, during the third week after relining, when the lining had been considerably eaten away and the capacity of the furnace increased. In this respect they represent a phase of work just opposite to that represented by the last seven charges in Table A.

In Table B nine charges are tabulated the total weight of which is 9,944 Kgs. Deducting 497 Kgs. (about 5 per cent) for loss, we have a total product of 9,447 Kgs.,

the making of which occupied the furnace for 98 hours, 55 minutes.

Allowing about an hour and a quarter during each charge when the current was off, this gives approximately 87·5 hours during which electrical energy was supplied or *9 hours per ton of steel.*

These figures show that, as the lining wears and the capacity of the furnace becomes greater, there is a slight decrease in efficiency, and this agrees with the information given to me by Major Stassano.

The two furnaces experimented with are of practically the same power and capacity and we may take the average time during which energy must be supplied as about the mean of the two figures obtained above, which would be about $8\frac{1}{2}$ hours per ton of steel produced.

The only essential difference between the two furnaces is that the revolving furnace works at 100 volts while the tilting furnace works at 150 volts. The latter voltage is according to Major Stassano rather too high and tends to produce unsteadiness in the arc. It is probable that 120 volts would be better. I had no means of directly measuring the consumption of power in the furnaces, but for purposes of calculation I will take the readings of the voltmeter and ammeters which were on the circuit supplying the electrodes of the tilting furnace at a distance of about 50 feet from the furnace. The voltmeter showed 150 volts and the electrodes were controlled so as to keep the current at about 700 amperes, but at times there was considerable oscillation of the needle. As the current supplied to the furnace is three-phase, the product of volts and amperes must be multiplied by $\sqrt{3}$ and the power-factor (Cos. ϕ) is said to be 0·9.

Total Watts $= 700 \times 150 \times 1{\cdot}73 \times 0{\cdot}9$

$= 163{\cdot}5$ Kilowatts which is equivalent to about 220 h.p.

If, therefore, energy has to be supplied at this rate for

8½ hours to produce 1 ton of steel, the total energy used is approximately 1,390 K. W. hours per ton of steel.

If anything, this figure is too high as the current is allowed to drop towards the close of the operation and Major Stassano estimates that with this furnace the actual consumption of energy is between 1,100 and 1,200 K. W. hours.

It may be added here that in some trials made with the 1,000 h.p. furnace the consumption of energy is said to have been reduced to 800 K. W. hours per ton of steel and although I am unable to confirm this I have no doubt that a considerable reduction is to be expected with the larger furnace.

Working time of furnace.

For each ton of steel produced energy has to be supplied for about 8½ hours in addition to which about 1½ hours are spent in taking off slags, preparation for next charge, etc. The output of the furnace is therefore nearly 2½ tons per 24 hours, which means that the electric supply is used for 20 hours and idle for 4 hours per day. We have already seen that relining takes about ⅛ of the time of the furnace; adding the above loss we may estimate that the furnace is idle for ⅓ of its time so far as the electrical supply is concerned. This has got to be taken into account no matter in what way the electric power has to be paid for. If the power plant is owned by the users of the furnace, it will increase the capital and working charges; if the power is purchased by metre, it will to some extent tend to increase the rate; per unit and if purchased on a flat rate, it will have to be fully allowed for. In a large plant with several furnaces the loss of time due to relining can be completely avoided at the cost of installing a sufficient number of spare furnaces, and the other interruptions will tend to balance one another and permit of a good factor being maintained. The point is, however, one which must not be lost sight of in estimating cost of production from figures as to actual amount of energy required.

Composition of Charge and of Steel produced.

The charges enumerated in Tables A and B were composed of materials having the following composition per 100 parts:—

	C.	Si.	S.	P.	Mn.
Pig iron ...	3·8	1·8	0·01	0·02	0·37
Lathe turnings ...	0·3	0·1	0·06	0·06	0·53
Drillings, etc. ...	0·3	0·7	0·083	0·057	0·075
Foundry scrap ...	0·25	0·10	0·07	0·08	0·6
Ferro silicon ...	0·35	51·65	...	0·13	0·36
Ferro manganese	6·409	0·233	Trace	0·295	70·732

The composition of any of the charges can therefore be calculated, and as an illustration we will take charge No. 335 from Table B which was put through on the 9th January 1908.

From the weights of the various materials charged and their respective compositions as given above, the composition of charge No. 335 was—

C =0·56 per cent.
Si.=0·26 „
S =0·064 „
P =0·068 „
Mn.=0·91 „

The steel produced from this charge had the following composition according to an analysis made at Turin:—

Sample P_2.
C =0·22 per cent.
Si.=0·15 „
S =0·06 „
P =0·04 „
Mn.=0·45 „

A test piece of this steel, 16 mm. diameter and 100 mm. in length, gave a breaking strain of 12,067 Kgs., with an elongation of 19 mm. or in British units—

Tensile strength =38·3 long tons per square inch.
Elongation =19 per cent.
Reduction of area=52·36 per cent.

A sample (No. 309 P_4) was also taken from the steel produced from charge No. 309 tapped on 7th January 1909.

The composition of the charge was practically the same as the foregoing (No. 335) and the ingot was sent to Mr. Harbord for analysis and testing with the following results:—

COMPOSITION.	SAMPLE No. 309 P_4.
Carbon ...	... 0·126
Silicon ...	... 0·067
Sulphur ...	... 0·051
Phosphorus ...	... 0·033
Manganese ...	... 0·467

The following physical tests were made by Messrs. Kirkaldy & Sons:—

TEST No. Q. Q. 427.

Description:	Forged bar P_4 309, $1\frac{3}{8}''$ square.
Original diameter (turned)	... 0·618 inch.
Do area	... 0·300 square inch.
Elastic stress per square inch	42,800 lbs.=19·1 tons (long).
Ultimate do	... 61,900 lbs.=27·6 tons (long).
Ratio of elastic to ultimate stress ...	... 69·1 per cent.
Yield point by drop of steelyard ...	... 20·4 tons per sq. inch.

Contraction of area at fracture	...	60·3 per cent.
Extension	in 2 inches ...	36·5 ,,
	in 3 inches ...	27·3 ,,
	in 8 inches ...	14·1 ,,
Appearance of fracture	...	Silky; pitted.

TEST NO. Q. Q. 428.

Another bar stamped P_4 309, $\frac{13}{16}''$ square, was subjected to 12 blows from weight of 100 lbs., falling 5 feet, without breaking. The bar was reversed after each blow. Greatest total deflection 0·72 inch.

The steel is used for small castings and it will, I think, be admitted both from the composition given above and from the results of the tests, that the material is very excellent for the purpose. Numerous blacksmith's tests were also made from the various charges, the usual procedure being to draw part of an ingot under the hammer into a bar about $\frac{3}{8}''$ square. The bar was heated rather above dull redness and then quenched in water and bent over on itself cold. In every case the bending was effected without any flaw or crack being produced.

In comparing the composition of the charge with that of the steel produced, it may be noted that the charge is fairly high grade and that the reduction of impurities in the cast steel is not very great compared with the reduction effected in other processes for the production of high grade tool steels. On the other hand, it must be remembered that in the case of the charges quoted in Tables A and B there is no need for great purification as a very high class product is not required.

For the production of a higher grade product, further manipulation is required involving, no doubt, expenditure of energy, but there is no reason why the highest grade of steel should not be produced in this furnace, and I am

informed by Major Stassano that very high grade tool steels have been produced in experimental trial runs.

Cost of Smelting Steel Scrap.

The following figures of the cost of producing one metric ton of steel were given to me by Major Stassano. The figures refer to work with one furnace of 200 h.p. and one of 100 h.p. giving a combined output of 4 tons of steel per 24 hours. (1 Lira=10d.)

	Lire.
Charge.—Scrap steel, etc., 1,050 Kg. at Lr. 100 per ton	105
50 Kg. Limestone at Lr. 20 per ton ...	1
8 Kg. Ferro Manganese, Ferro Silicon at Lr. 450 per ton...	3·60
1 Kg. Aluminium at Lr. 4·5 per Kg. ...	4·5
Labour.—2 Shifts of 7 men and 1 foreman; each man received Lr. 4 and foreman Lr. 5; for output of 4 tons this gives per ton ...	16·50
Electrodes.—Average consumption per ton is 4 Kg.; at Lr. 0·4 per Kg.	1·60
Breakage and waste estimated at ...	2·40
Lining.—Of furnace	25·00
Power.—1,300 K. W. hours (including lighting) supplied by the Electric Power Company at Lr. 0·02 per K. W. hour	26·00
General expenses.—Office, interest, etc. ...	40·00
Total per ton of steel ...	225·60

In English money this is approximately £9 per ton.

Several of the above items are high owing to the smallness of the plant, and for furnaces working on a larger scale it is obvious that the charges for general expenses, labour and power would be reduced and probably some of the other items also.

Major Stassano estimates that a furnace of 1,000 h.p. would produce 16 tons per 24 hours with the same labour as given above.

The cost for labour would therefore be reduced to Lr. 4 per ton.

The power (taken at 800 K. W. hours) would be reduced to about Lr. 16 and the general expenses to Lr. 10 per ton.

If all the other items remain as before, the reduction would amount to Lr. 52·50, giving a total cost of about Lr. 173 or rather under *£7 per ton.*

Cost of furnace.—The furnace is undoubtedly of an expensive type. The following figures refer to those constructed at Turin :—

		£
200 h.p. furnace—revolving-type, complete, costs Lr. 20,000	... ... =	800
200 h.p. furnace—tilting type, costs Lr. 15,000	... ... =	600
1,000 h.p. furnace—revolving type, costs Lr. 50,000	... ... =	2,000

It must be noted, however, that costs for iron and steel work are high in Italy and there is no doubt that these furnaces could be made elsewhere at considerably lower figures.

Refractory lining.—This is made of magnesia bricks. A lining for a 200 h.p. furnace costs Lr. 1,000=£40 and for a 1,000 h.p. furnace, Lr. 5,000=£200.

A lining lasts about 22 or 23 days and the material for relining costs $\frac{2}{3}$ to $\frac{3}{4}$ of the original amount.

At Turin the magnesia bricks, which are obtained from Austria, cost Lr. 300 (£12) per ton. This is undoubtedly a high figure. The bricks have the following composition :—

MgO	= 84—85	per cent.
SiO_2	= 1·5	per cent.
Fe_2O_3, Al_2O_3	= 5— 4	per cent.
CaO	= 5— 4	per cent.

While I was at Turin a trial was being made with silica brick for the lining of the roof of the furnace, but I have not yet heard the result.

In localities more favourably situated for the supply of magnesite and, if the bricks are manufactured at or near the smelting works, the cost of the refractory lining as indicated above should be capable of very material reduction.

Electrodes.—The electrodes used at Turin are imported and cost Lr. 0·4 per Kg. The waste material can be resold at Lr. 0·08 per Kg.

The electrodes in use did not appear to me to be of very high quality and an improvement in this respect would save waste and breakage as well as loss of time. If good electrodes were manufactured at the smelting works, the cost should be capable of reduction and the advantage would be gained of using up broken pieces and remnants to make new electrodes. The figure, Lr. 4, for the cost of electrodes per ton of steel as given by Major Stassano appears to me to be fair and reasonable under present conditions but ought, I think, to be capable of reduction in the manner above indicated. To determine the cost of electrodes would require close observation of the operations over an extended period and naturally I was unable to secure this. A few observations which I made with the 200 h.p. Tilting furnace gave the following results :—

An electrode 1,500 mm long and 80 mm diameter was found to weigh 11·7 Kg.; a length of 100 mm weighs therefore 0·78 Kg.

(1) The three electrodes were pushed forwards towards the centre of the furnace until their points were about the diameter of an electrode apart. They could not be made to touch for fear of breaking them and the distance between the points had to be estimated. They were then retired and the arcs started.

After 5½ hours run the current was stopped and the

points of the electrodes again brought towards the centre to the same distance apart as before as closely as could be judged. By measuring the respective positions of the electrode holders it was found that the electrodes had been shortened by 77 mm., 50 mm. and 18 mm. respectively, or a total of 145 mm.

The electrodes tend to wear down to the shape of an acute truncated cone, the thin end being about 50 mm. in diameter, and I estimate that the weight of the electrode actually consumed will not be very different from the weight of a piece of new electrode equal in length to the distance by which the electrode is advanced during consumption.

The total distance advanced by the three electrodes was, as given above, 145 mm. and this at 0·78 Kg. per 100 mm. gives a total weight of 1·131 Kg. in 5½ hours or *0·205 Kg. per hour.*

(2) Another observation on similar lines was made over a run of 8 hours and the three electrodes were reduced in length by 500 mm. representing 3·9 Kg. and including a small piece which broke off No. 2.

This gives a consumption of *0·488 Kg. per hour.*

(3) In the third test each electrode was taken out and weighed with its holder at the beginning and end of the experiment.

No. 1.—Original weight	... ...	73	Kg.
Weight after 18 hours run	...	69	,,
Consumption of electrode	...	4	Kg.
or 0·222 Kg. per hour			
No. 2.—Original weight	... ...	71·4	Kg.
Broke off short after 2 hours.			
Weight including broken portion	... ...	70·4	,,
Consumption	... ...	1·0	Kg.

New electrode, weight	... 74·4	Kg.
Weight after 17¼ hours	... 71·4	"
Consumption ...	... 3·0	Kg.

Total consumption 4 Kg. in 19¼ hours=*0·208 Kg. per hour*

No. 3.—Original weight ...	... 73·5	Kg.
Weight after 18 hours	... 69·0	"
Consumption ...	... 4·5	Kg.

or 0·25 Kg. per hour.

The consumption of the three electrodes was therefore *0·68 Kg. per hour.* This figure is higher than that obtained in the previous observations, but the electrodes were not so good in quality and small pieces broke off them several times.

The average of the three sets of observations gives $\frac{0·205+0·488+0·68}{3} = 0·457$ Kg. per hour. If we reckon that the furnace takes 8½ hours to produce 1 ton of steel, the consumption works out at *3·88 Kg. per ton of steel,* which agrees very well with Major Stassano's figure of 4 Kg. If we go by the third experiment only as being the most accurate, we get 0·68 Kg. per hour or *5·45 Kg. per ton of steel* which, considering the inferior quality of the electrodes, also tends to confirm Major Stassano's estimate. The cost of these 4 Kg. of electrode is, at Turin, Lr. 1·6 and in addition Major Stassano allows a charge of Lr. 2·4 for breakage and waste making a total of Lr. 4 (or 3s. 4d.) per ton of steel. This appears to me to be a fair allowance and one which is capable of reduction if better material is used and if the electrodes are manufactured at the works.

III. PRODUCTION OF STEEL FROM ORE IN THE STASSANO FURNACE.

The production of steel from scrap as described in the previous section can be and is being effected in the Stassano furnace. The question as to whether the furnace is more suitable or less suitable for that purpose than various other types of furnace which have been devised or which are at present in use, is a matter for discussion which may for the present be left open.

On the other hand, the reduction of iron ore and the direct production of steel therefrom in one operation is a process which Stassano has specially set himself to develop and for which his furnace has been specially designed and no one else has endeavoured to attain the same end nor appears to be anxious to do so.

Some ten years ago Stassano set himself to work on this problem and an account of his aims and arguments together with a record of certain trials made and a description of the various types of furnace experimented with will be found in a pamphlet * published by the inventor in 1902.

I think I am right in saying that steel metallurgists have been consistently opposed to the process and that they regard it as impractical. It is certainly a distinct departure from established precedent and from the usual well-tried methods of work and, although metallurgists may be prepared to admit that it is possible to put a rich pure ore into the electric furnace and produce therefrom in one operation a material which is undoubtedly steel, they appear to consider that the results are liable to be too uncertain to form the basis of a commercial process for the manufacture of so definite and delicately balanced a product as that now demanded from the modern steel maker.

* Processo Termo-Elettrico per la Riduzione dei Minerali di Ferro. Ernesto Stassano, Roma, 1902.

It was with considerable interest, therefore, that I accepted Major Stassano's invitation to witness the latest trials of this process in the new 1,000 h.p. furnace, but unfortunately, for reasons which I have already explained, the trials did not come off. I however obtained Major Stassano's consent to make some trials of the process with one of the 200 h.p. furnaces, then in commission at Turin for the manufacture of steel from scrap, for the sake of watching the working of the furnace and of gaining some preliminary information which might be useful in the event of further trials being considered desirable. Before describing the experiments which were made, I will briefly refer to some points in the pamphlet published by Major Stassano in 1902.

EARLIER EXPERIMENTS AT DARFO.

The furnace used at Darfo for the experiments on the reduction of iron ore was a small non-rotating furnace of about 100 K. W. capacity. The current used was monophase and was led into the furnace by two moveable carbon electrodes giving a single arc. The maximum voltage was 100 and the maximum current 1,000 amperes. The ore used—the specular hæmatite of the Island of Elba—was of exceptional purity and its composition is given by Stassano as follows:—

Fe_2O_3	... ...	92·020
MnO	... ...	0·619
SiO_2	... ...	3·790
CaO, MgO	... ...	0·500
S	... ...	0·058
P	... ...	0·056
Moisture	... ...	1·720

This material was pulverised and made into bricquettes with sufficient limestone and coke for reduction, the binding material used being tar.

The composition of the bricquettes was as follows :—

Iron ore	1,000
Limestone	125
Coke	160
Tar	120

The composition of the limestone, coke and tar was :—

Limestone :—

CaO	= 51·210 per cent.
MgO	= 3·110 „
SiO_2	= 0·900 „
Al_2O_3, Fe_2O_3	= 0·500 „
CO_2	= 43·43 „

Coke :—

Carbon	= 90·420 per cent.
Ash	= 3·880 „
Moisture	= 5·700 „

Tar :—

Carbon (fixed)	= 59·200 per cent.
Hydrocarbons	= 40·500 „
Ash	= 0·270 „

The following statement gives the essential details of five experiments :—

No. of experiment.	Charge of bricquettes. Kgs.	Weight of soft iron or steel produced. Kgs.	Percentage of iron charged recovered in product	Duration of operation. Minutes.	Energy consumed. K. W. Hours.	Energy consumed per 1,000 Kgs. of product. K. W. Hours.	Remarks
					$\cos\phi = 0.8$		
1	61·10	26·00	91·55	86	114·666	4,410	Volts 100, amperes 1,000 throughout the operation.
2	49·50	22·00	91·33	86	114·666	5,212	Do do
3	57·00	22·00	91·27	82	109·333	4,970	Do do
4	56·20	24·80	94·91	90	90·133	3,634	First 30 minutes 100 volts, 1,000 amps.
...	...	...	...	...	...	...	Next 30 „ 80 „ 800 „
...	...	...	...	...	...	...	Next 20 „ 70 „ 600 „
...	...	...	...	...	...	...	Last 10 „ 100 „ 1,000 „
5	70·25	30·800	94·38	120	97·200	3,156	First 20 „ 80 „ 800 „
...	...	...	...	...	...	...	Next 20 „ 100 „ 1,000 „
...	...	...	...	...	...	...	Next 30 „ 70 „ 600 „
...	...	...	...	...	...	...	Next 30 „ 50 „ 500 „
...	...	...	...	...	...	...	Last 20 „ 100 „ 1,000 „

In the above statement it may be noticed that there is some discrepancy in the figures of the 3rd experiment. Either the weight of charge or the weight of product or the percentage of extraction is incorrectly stated.

The composition of the soft iron produced in these experiments was :—

Experiment	1	2	3	4	5
Fe ...	99·647%	99·704%	99·690%	99·742%	99·764%
Mn ...	0·106	0·095	0·109	0·083	0·092
Si ...	0·048	0·022	0·028	trace	trace
S ...	0·073	0·062	0·046	0·065	0·059
P ...	0·0055	0·024	0·013	0·0016	0·009
C ...	0·120	0·092	0·113	0·091	0·090

From the thermal equations of the various reactions which are considered to take place Stassano has calculated the "thermal efficiency" of the furnace in these five experiments, or in other words, the ratio of the quantity of heat actually required for the reactions to the quantity of heat supplied electrically, and he obtains the following figures :—

No. of experiment	1	2	3	4	5
Thermal efficiency % ...	45·65	37·07	41·11	55·02	61·33

A consideration of the data afforded by these experiments shows that from pure materials, such as those used, it is possible to produce a pure soft iron or steel in one operation and that the character of the product remains

very fairly constant and would no doubt be still more so in operations conducted on a uniform plan.

Of the iron originally contained in the ore there is a recovery of from 91 to 95 per cent, or a loss of from 5 to 9 per cent,—a figure which compares very favourably with any existing process for the reduction of ore to pig iron and its subsequent conversion to steel.

With regard to elimination of sulphur, from one-fourth to half of the sulphur present in the ore has been removed. The amount in the ore is however so small that no special precautions for its removal are necessary, nor do any seem to have been taken. This is a point to which I shall refer later, but so far as the present experiments go, the information afforded is of little value in regard to ores which may suffer from a high percentage of this undesirable element.

Similar remarks apply to the phosphorus owing to the small amount contained in the ore, but it will be noticed that even this small amount has been very considerably eliminated (from 74 per cent to 98 per cent being removed) as might be expected from the very basic character of the slag which would be formed under the conditions of the experiments.

The energy supplied to the furnace varied very considerably in the different experiments and decreased as the weight of the charge increased, a result which tends to show that the furnace was not working at its full capacity and that heat was being wasted.

The effect of reducing the voltage or current during a portion of the run as in experiments 4 and 5 is also very marked and gives as the maximum result a little over 3,000 K. W. hours per ton of steel produced, with a calculated thermal efficiency of over 60 per cent.

I think there is little doubt that these figures could be improved upon with a larger furnace furnished with multiple electrodes, such as the new revolving furnace of 1,000 h.p. recently erected at the Forni Stassano at Turin.

The advantage to be derived from reducing the power of the furnace for a portion of the run is, of course, a question of cost and arrangement and is obvious if the power is paid for by meter according to the total energy consumed. If, however, the power is paid for on a flat rate, it would be necessary to have several furnaces in commission at the same time and arrange their working, so that while the power in some is being increased, in others it is being diminished so as to keep the load factor as uniform as possible. The experiments show clearly the advantage of reducing the power during what may be called the period of gestation and these advantages would, I think, be still more marked in dealing with less pure materials from which the elimination of impurities would be imperative and for which the time element is of the greatest importance. To gain this time without expending energy in the production of unnecessary heat is, I think, a problem of very great importance in view of the very disproportionate extension of the time of operation which comparatively small quantities of impurity involve. It is very probable, as claimed by Stassano, that the rotating type of furnace which he has devised would materially help to reduce the time required.

These early experiments on the direct reduction of iron ore to soft iron or steel, and Stassano's claims as to the feasibility and advantages of such a process and its applicability in places where fuel is scarce, have been the subject of a good deal of comment most of which has been of an adverse character.

The experiments have undoubtedly demonstrated that a soft steel can be made from ore in the electric furnace and that the material produced maintains a very fairly constant character, but exception has been taken to the fact that remarkably pure materials were used for the experiments which therefore afford no guide as to the results which would be obtained from the poorer and less pure ores commonly available for smelting purposes and

with such ores it has been held that Stassano's process would be unlikely to work satisfactorily and to yield a product the type of which would be sufficiently reliable and controllable to suit the need of the modern steel maker. Further, most other workers on the subject appear to consider that if the economic conditions are such as to render an electrical smelting process possible, the most desirable plan would be to first produce a pig iron and to subsequently refine the pig to the extent necessary for the various grades of steel required, thus following the usual practice in vogue in fuel-fired furnaces. It is considered that this latter plan would have many advantages particularly where large outputs have to be dealt with. If any considerable industry is to be developed in electrical smelting of iron ore and production of steel, large outputs for individual plants are a necessary factor for success; and unless or until working on a large scale is rendered practicable, the industry must remain a restricted one in the lines of special and high-priced steels and for refining purposes. Of recent years several attempts have been made to develop an electric furnace suitable for the production of pig iron from ore on a commercial scale. Several experimental plants have more or less demonstrated the possibility of the production of pig iron from ore on a small scale, but I am not aware that any furnace for working on a large scale has yet been devised which is satisfactory on the technical side or which could compete with the products of fuel-fired furnaces even when the latter have to be imported from long distances.

I had hopes that the proposed experiments with Stassano's 1,000 h.p. furnace would throw some light on the various objections which have been raised against his process; but as these did not come off I endeavoured during my visit to Turin to obtain some further information than that afforded by the Darfo experiments by means of a few trials in a furnace of 200 h.p. which Major Stassano kindly placed at my disposal. The furnace used

was the tilting furnace already referred to in connection with the production of steel from scrap, on which work it was at the time in commission, and the changes from the scrap to the ore processes and *vice versa* were made without any break or delay or preparation of the furnace.

TRIALS MADE AT TURIN.

Character of ore used.

My first object was to obtain an ore which would not be regarded as unusually rich or pure, but rather the reverse. Major Stassano obtained for me some iron ore which after calcination was carefully sampled and found to have the following composition:—

Iron ore dried at 212° Centigrade.	(No. A)
Silica	15·110
Ferric oxide	68·130
Ferrous oxide	Trace
Alumina	1·450
Oxide of manganese ...	3·110
Lime	2·306
Magnesia	7·205
Sulphur	0·324
Phosphoric acid ...	0·052
Loss on ignition, organic matter, combined water, CO_2.	2·130
Total ...	99·817
Moisture	0·90
Metallic iron	47·69
Phosphorus	0·023

It will be admitted that this is by no means a rich or favourable ore. Mr. Harbord who kindly made this analysis for me, as well as most of those quoted in this section, remarks as follows:—

"From the analysis of the ore and bricquette it will be seen that although the ore is fairly high in iron and low in phosphorus, the sulphur is exceptionally high and even the iron content is below what are regarded as high class hæmatite ores. The hæmatite ores used in England average 50 per cent of metallic iron and rarely contain more than 0·05 per cent of sulphur and the difficulties of producing steel of the highest class from ore containing over 0·30 per cent of sulphur are undoubtedly great."

I hoped that the phosphorus in the ore would also be high, but as there is no great difficulty in getting rid of a considerable percentage of phosphorus under the conditions of the electric furnace, the low content of this element is not of very much consequence.

Bricquettes.

From an analysis of the ore made at the works the following composition for the bricquettes was adopted:—

Ore	...	1,000 parts	63	per cent.
Charcoal	...	240 „	15	„
Marble	...	350 „	22	„

The wood charcoal used contained—

Moisture	...	...	7·7	per cent.
Ash	...	...	6·7	„
Carbon by difference		...	85·6	„

The various materials were pulverised and mixed with a little tar and made into bricquettes in a small press, the size of the bricquette being a circular disc about 3″ in diameter by 1″ thick; the bricquettes were sampled and found to have the following composition:—

Analysis of bricquettes (No. B_1). Dried at 212° C.

Silica	... ...	17·560
Ferric oxide	... ...	41·131
Ferrous oxide	... ...	Trace
Alumina	... ...	1·673
Oxide of manganese	...	1·694
Lime	... ...	11·240
Magnesia	... ...	4·610
Sulphur	... ...	0·347
Phosphoric acid	... ...	0·050
Loss on ignition, organic matter, combined water, CO_2	...	21·600
Total	...	99·905
Moisture	... ...	1·04
Metallic iron	... ...	28·79
Phosphorus	... ...	0·03

TRIAL A.

This was a trial run for the production of mild steel containing about 0·2 to 0·3 per cent of carbon and not more than 0·05 per cent of sulphur and 0·05 per cent of phosphorus.

400 Kg. of bricquettes were used containing approximately 115·16 Kg. of iron.

At 10 A.M., on the 3rd January 1908, about 900 Kg. of mild steel, produced from scrap, were tapped from the furnace and cast in a number of moulds.

10-30.—The charging of the bricquettes commenced, the bricquettes being shovelled into the furnace through the side door.

10-45.—250 Kg. had been charged and door shut.

10-50.—Current turned on at 150 volts and about 700 amps. Ampere meter very jumpy. Much gas issuing from the cracks of the charging door which is the only opening into the furnace, the top being complete without any escape port for the gases.

11-20.—Current fairly steady at about 700 amps.

12 noon.—Opened door. Charge pasty, melted in the centre and boiling actively.

Charged 75 Kg. of bricquettes.

12-50 P.M.—Charge nearly all melted and boiling actively. Charged 75 Kg. bricquettes.

Total charge put in—400 Kg.

2 P.M.—Charge completely fused, gas ceased burning at charging door.

Cut off current.

2-30 to 2-40 P.M.—Furnace tilted and slag poured off. Slag very fluid—weight 157 Kg.

2-45 P.M.—Closed tap, put furnace upright and charged 7 Kg. of calcium carbide and some pieces of metal from bottom of slag pot.

2-50.—Turned on current.

3-40.—Gave furnace a few slow oscillations.

3-56.—Opened tap, turned off current and poured the steel into ladle. Very little slag.

At this point, unfortunately, the bottom came out of the ladle and the steel poured into the casting pit where it solidified as a brittle spongy mass, the weight of which was 129 Kg.

TRIAL B.

The bricquettes used were similar to those used in Trial A, but a charge of 800 Kg. was used as the furnace was by no means working up to its full capacity with the charge of 400 Kg. previously used.

The object as before was to produce a mild steel containing from 0·2 to 0·3 per cent of carbon and with sulphur and phosphorus each not exceeding 0·05 per cent.

At 4-25 P.M. on the 3rd January, immediately after the conclusion of Trial A a charge of scrap was put in the furnace and finished by 12 P.M. At 1 A.M. on the morning of the 4th another charge of scrap was put in and tapped at 9-45 A.M. and I at once commenced charging bricquettes for Trial B.

10-5 to 10-25.—Charged 299·3 Kg. of bricquettes.

10-30.—Current switched on, very jumpy at first, but fairly steady by 10-50. Volts 150, amps. about 750.

12 noon.—Charge fairly well melted. Charged 100·7 Kg.

1-25.—Flame dropped. Current between 750 and 800 amps.

1-40.—Tapped 1st slag. Weight 136·7 Kg. Threw in 5 Kg. of calcium carbide.

1-45 to 1-55.—Charged 238 Kg. of bricquettes; action very brisk; much gas coming off. Current somewhat jumpy.

3-0 to 3-10.—Charge all melted and bubbling very briskly. Charged 162·3 Kg.

Total charge 800·3 Kg. of bricquettes.

3-20.—Current steady, about 775 amperes.

4-30.—Opened door; bath boiling briskly. On shutting furnace door flame ceased to issue.

4-50.—Gave furnace a few tilts and tapped slag; weight of slag 161·2 Kg.

5-0.—Took Dip sample B_8. from bath.

5-10.—Charged 10 Kg. of calcium carbide. Current between 500 and 600 amps.

5-30.—Rabbled bath, gas coming off quietly, but not burning outside the door.

5-50.—Tapped 84 Kg. of metal. After putting a little aluminium in the ladle, cast into—

one large ingot ...	... No. 290—B_7
one small ingot ...	... B_4

and some box castings.

The metal teemed well, the castings were sound with little piping.

This completes Trial B the details of which will be discussed later.

It will be noticed that a portion only of the metal was tapped from the furnace, the reason being that during the course of the trial I decided to tap about half the metal for investigation as to how far the object of the trial had been attained, namely, the production of soft steel of good quality, and then to make an attempt to produce a higher carbon steel from the metal remaining in the furnace. This attempt I call Trial C.

Trial C.

In this the object was to make a steel containing about 0·6 per cent of carbon by adding a calculated weight of a pure pig iron to the metal in the bath.

A rough calculation showed that the iron in the 800 Kg. of bricquettes would be about 240 Kg. and allowing 5 per cent loss in the slag this reduces to 232 Kg. of which 84 Kg. had been tapped in Trial B, leaving 148 Kg. in the furnace.

	148 Kg. metal at 0·3 per cent C	=·444 Kg. of carbon.
	15 Kg. of pig iron at 3·8 per cent C	=·57 ,,
Total	163 Kg. of metal	=1·014 ,,

which gives about 0·62 per cent of C for the final product. On this basis 15 Kg. of pig iron containing 3·8 per cent of carbon were thrown into the bath at 6 P.M.

At 6-7 the bath was stirred and at 6-10 tapped.

The weight of metal tapped was 110·68 Kg. but probably all the metal did not come out of the furnace owing to irregularities in the hearth.

The metal was cast into—

one large ingot No. 290—C_4

two small ingots and parts of two large ingots.

The large ingot was about 4″ diameter by 16″ long. The metal teemed well and the ingots were sound with little piping.

RESULTS OF TRIAL A.

Owing to the failure of this trial, on account of the ladle breaking at the last moment, I have not thought it worth while to make more than a very partial examination of the products.

Slag.—The weight of this was 157 Kg. and it contained—

SiO_2 ...	...	... 33·56 per cent
Fe ...	...	... 11·40 „
Sulphur	...	... 0·235 „

The amount of Fe lost in the slag is very high, being nearly 18 Kg. out of a total of 115·16 Kg. contained in the charge—a loss of over 15 per cent.

The weight of steel produced would therefore not exceed about 97 Kg.; but as about 129 Kg. were picked up from the casting pit, it is evident that some other material had been picked up with it and the analysis cannot be relied on.

A partial analysis of some of this steel showed—

Carbon	...	... 0·27 per cent.
Sulphur	...	... 0·13 „
Phosphorus	...	... 0·049 „

The carbon is about what was required, but the sulphur is very high and either the metal had not been desulphurised or some materials containing sulphur had got mixed with the molten steel in the pit.

RESULTS OF TRIAL B.

The Slag.

Composition.

	1st slag. (136·7 Kg.)	2nd slag. (161·2 Kg.)
Silica	36·960	34·640
Ferric oxide	2·200	2·200
Ferrous oxide	10·581	10·800
Alumina	1·900	1·880
Oxide of manganese ...	4·784	4·510
Lime	25·580	28·301
Magnesia	18·340	17·060
Sulphur	0·184	0·185
Phosphoric acid ...	0·110	0·138
Metallic iron	9·86	9·94
Phosphorus	0·048	0·06

In its general character the slag tends to approach some of those produced in blast furnaces making white iron, but the silica is low and the oxide of iron, oxide of manganese and magnesia are unduly high, and in these respects it tends to resemble a moderately acid open hearth slag in which some lime has been replaced by magnesia.

Loss of iron.

The slag contains 9·9 per cent of iron and as there is a large amount of it the loss has been very considerable.

The iron contained in the slag amounts to 29·5 Kg. and as the amount of iron in the charge was 230·32 Kg.

there has been a loss of 12·8 per cent of the metal. For purposes of calculation we may estimate the total weight of steel produced as 200 Kg. It is possible that less iron would have been lost had the slags been made more basic by a larger addition of lime.

There is no doubt that with an ore containing less slag-forming material, the loss of iron would be considerably reduced and the above figure tends to confirm the statement that the loss in the Darfo experiments on the rich ores of Elba varied from 5 to 9 per cent with an average of about 7·5 per cent. It must also be remembered that in the experiment under discussion we are dealing with the direct production of steel from the ore and the loss of iron has to be compared not only with that due to the production of pig in other smelting processes, but with the loss during the manufacture of steel from pig in addition; and bearing this in mind the loss of 12·8 per cent on such an ore is not so unfavourable.

Oxide of manganese.

In ordinary blast furnace work with a high temperature and basic slag the greater portion of the manganese passes into the iron, and it is remarkable that in the present case the converse has occurred. The ore used contained 3·11 per cent of oxide of manganese; the slag contained 4·6 per cent of MnO and the steel 0·108 per cent of Mn.

The 800 Kg. of bricquettes charged contained	10·52	Kg.	of Mn.
The slag contains	10·62	,,	,,
The steel produced contains ...	0·216	,,	,,

which figures show that practically the whole of the manganese has gone into the slag.

This point is especially interesting in view of the moderately basic character of the slag and the extent to which sulphur was finally eliminated, a point which will be discussed later.

The weight of magnesia in the charge is 36·88 Kg., and in the slag is 52·00 Kg.; about 15 Kg. has therefore been derived from the lining of the furnace, a portion of which would doubtless have been saved by using more lime in the bricquettes.

Magnesia.

The amount of sulphur in the ore was 0·324 per cent and in the bricquettes 0·347 per cent. The latter figure would indicate some sulphur in the flux and charcoal used.

Sulphur.

The bricquettes charged contain 2·776 Kg. of sulphur,

and the slag ...	... 0·551	„
leaving a balance of	... 2·225	„

to be accounted for.

From the analysis of the dip sample (B_3 quoted below) of the bath of steel after removal of the slag, the sulphur remaining in the steel was 0·241 per cent, which accounts for another 0·482 Kg. of S.

These results show that the large amount of sulphur originally contained in the charge has been disposed of as follows:—

Contained in the slag	... ...	20 per cent
„ „ steel	... ...	17 „

The remaining 63 per cent has disappeared presumably by volatilization.

These results are noteworthy as being distinctly different to what occurs in blast furnace practice, in which usually quite a small proportion of the sulphur passes into the metal and the bulk of the remainder passes into the slag, while comparatively little passes off by volatilization. Doubtless if the conditions had been such as to cause the reduction of a large part of the manganese and its absorption by the metal, the amount of sulphur in the latter would have been considerably reduced; and as regards the 63 per cent, which I assume to have been volatilized, it may be noted that the conditions of the furnace used were very different to those in the interior of a blast

furnace. In the former any sulphur which did not immediately combine with the lime to form calcium sulphide would have a very good opportunity of escaping from the large surface of the comparatively thin layer of bricquettes and molten material on the hearth, while in the blast furnace any volatilized sulphur would have to pass up through the heated fluxes in the shaft of the furnace and would have plenty of opportunity of combining with the fluxing components of the charge.

It would be an interesting and important fact, if satisfactorily established, that in such a furnace a highly sulphurous ore loses a large part of its sulphur without enriching either the iron or the slag.

Phosphorus.

The amount of phosphorus originally present in the ore being small ($P=0{\cdot}023$), the results are less important than one could have desired. The following figures show the results of the trial:—

Weight of phosphorus in charge	...	0·184 Kg.
Do slag	...	0·162 „
Do (by difference) steel *	...	0·022 „

Thus about 88 per cent of the phosphorus passed into the slag and about 12 per cent into the metal. This is very different from what occurs in the smelting of ores in the blast furnace where practically the whole of the phosphorus passes into the metal. This point is interesting although the total amount of phosphorus in the ore was small and the results may not be a guide to what would occur with an ore high in phosphorus. It is probable that the feebly reducing character of the charge had something to do with this unlooked-for result, and this seems to be

* The percentage of phosphorus in the dip sample of the bath (*vide* Sample B_3 on page 42) was found to be only 0·003 per cent, which would mean a total of 0·006 Kg. of phosphorus in the steel. I think this figure is undoubtedly too low and due to the dip sample being taken from the surface. The percentage of phosphorus in the mild steel tapped from the bath was found to be 0·015, which would mean a total of 0·03 Kg. of phosphorus in the bath, and this is a more probable figure and might be used instead of the difference figure given above, without materially affecting the argument.

borne out by the fact that a certain amount (2·2 per cent) of Fe_2O_3 remained unreduced in the slag and that the amounts of FeO and MnO in the slag are proportionately large. The retention of phosphorus in the slag is perhaps more comparable to what takes place in an open-hearth process, but at the same time it must be noted that the slag was essentially a smelting slag for fluxing the gangue of the ore and that no special refining slag was used for the elimination of phosphorus from the smelted metal. It is very probable that in dealing with more phosphoric ores it would be necessary to apply a special refining slag after the removal of the smelting slag in order to reduce the phosphorus within reasonable limits.

Quantity of Carbon used.

The bricquettes contained 240 parts of charcoal to 1,000 of ore containing 476·9 parts of metallic iron. Taking the loss of iron at 13 per cent, this means 240 parts of charcoal consumed for 415 parts of iron produced or 575 Kg. of charcoal per metric ton of steel. This factor is of importance in a country where fuel is scarce and expensive, and for comparison I may briefly refer to the following figures.

In the experiments made for the Canadian Commission at the works of Messrs. Keller Leleux & Co. at Livet, France, Mr. Harbord reports that the amount of coke used in producing pig iron in the electric furnace was approximately one-third of the weight of pig, or 340 Kg. per metric ton. It is probable that had charcoal been used the weight would have been greater.

From the experiments at Sault Ste Marie, Canada, with a Heroult furnace producing pig iron, Dr. Haanel estimates that half a ton of charcoal would be required per ton of pig produced.

The advantages in regard to consumption of carbon in the experiments at Livet and Sault Ste Marie are more

apparent than real, as in both cases the ore used was of considerably higher grade than in the Turin trials, while the amount of CO_2 in ore and flux was much lower, thereby reducing the amount of carbon required for its conversion to CO.

In the case of a rich ore such as that used at Darfo, Stassano estimates that 250 Kg. of Coke (C=90 per cent) and 190 Kg. of Tar(C=59 per cent)—making a total of 337 Kg. of carbon—would be required per ton of steel produced.

These figures tend to show that for smelting iron ore in an electric furnace, from one-third to half a ton of charcoal or coke is required per ton of pig iron or steel produced.

For comparison one may take it that a blast furnace requires from about 900 to 1,100 Kg. (or an average of 1 ton) of either good charcoal or coke per ton of pig iron produced. To convert this iron to steel by an open hearth process would probably require a further half ton of fuel per ton of steel.

For the production of steel from ore, therefore, whether direct or indirect, we may take it that the electric furnace will require only from one-fourth to one-third of the amount necessary for smelting with fuel furnaces.

These figures are of importance in the South of India, as there are no local supplies of coke and where imported coke would be either expensive or inferior or both and where attempts hitherto made to start smelting on a large scale by means of charcoal have failed owing to the difficulty or impossibility of obtaining sufficiently large and lasting supplies of charcoal. I do not mean to say that this difficulty was the only cause of failure, but it made itself felt at quite an early stage and would, I think, have proved insuperable had the experiments been continued for any time on a large scale.

The Steel from Trial B.

Immediately after the second slag had been poured off a dip sample (No. B_3) was taken from the bath of metal.

It is on the analysis of this sam
calculation as to the influence an
and the results of simple smeltin

Composition of dip sample B_3 :-

Carbon	...
Silicon	...
Sulphur	...
Phosphorus	..
Manganese	...

From this it will be seen that
the percentage aimed at, *viz.*, bet
0·3 per cent. In trial A also the
correct, *viz.*, 0·27 per cent. The
results aimed at and those obtain
doubtful as to how far these resu
cular composition of the charge
the operator. I did not mysel
carbon which the steel was to
Major Stassano's proposal to pro
0·2 to 0·3 per cent of carbon. T
suggested as a result of previo
furnace, and I very much doubt
for the steel to contain 0·5 to 0·6
a material would have been prod
simple smelting. I doubt if th
which is found in the steel has a
proportion of carbon in the char
think that under the conditio
furnace some 0·2 to 0·3 per cent o
in the bath even with considera
portion of carbon in the charge,
the iron takes up about 3½ pe
widely varying proportions of bu

In the experiments with the H
Ste Marie and with the Keller fu
were produced containing mostly

carbon, notwithstanding considerable variations in the amount of carbon in the charge, and it is evident that in these furnaces, as in the blast furnace, the total carbon in the pig is essentially dependent on the character of the operation modified by the presence of various impurities. In the Stassano furnace the character of the operation is essentially different from that in the Heroult or Keller furnace or from that in the blast furnace and hence a very different result as regards the normal carbon absorption is not to be wondered at. It would be interesting to know how far the absorption of carbon in the Stassano furnace is capable of being controlled or increased and whether it would be possible to produce in such a furnace an ordinary pig iron.

In this connection it is interesting to note the amounts of carbon dissolved in the soft iron produced in the five experiments at Darfo quoted above in which the nature of the ore and proportions of carbon used differed greatly from the corresponding ingredients in Trial B.

In Trial B the ore contained about 48 per cent of metallic iron, the amount of charcoal used per ton of product was 575 Kg. and the percentage of carbon in the product was 0·241 per cent.

From the experiments at Darfo we get the following figures :—

No.	Carbon used per ton of product. Kg.	Percentage of C in product.
A	360	0·12
B	350	0·09
C	398	0·113
D	...	...
E	344	0·091
F	350	0·09

These figures may at first sight seem adverse to the suggestion advanced above, that there is no very close relation between the amount of carbon absorbed and the amount of carbon used per ton of product, for the variations are on the whole parallel. On the other hand, they show, so far as they go, that to produce a slight increase in the actual weight of carbon absorbed, a very large increase in the weight of carbon used is necessary and that any attempts to regulate the percentage of carbon in the final product by altering the proportion of carbon in the charge would at least be commercially impracticable.

Fortunately it is of no consequence whether it is practicable or not, but what is of importance is that in smelting with what is to all intents and purposes the amount of carbon which is required for reduction purposes, the natural product seems to be a low carbon iron or steel and in this respect the Stassano furnace appears to differ essentially in its action from the Heroult and Keller furnaces which have been used for smelting ore. One of the most obvious differences is that the Stassano furnace is practically a hearth furnace used for ore-smelting while the other two are practically shaft furnaces and probably more nearly related to a blast furnace in regard to the distribution of charge and the character and sequence of reactions.

As remarked above, I am doubtful whether a pig iron could be produced in the Stassano furnace, but from the mild steel or iron which I have shown to result from the smelting operation there is no difficulty in producing a high carbon steel as I shall show later.

Silicon.

The amount of silicon present in the steel (0·024 per cent) is low notwithstanding the high temperature of the furnace and the siliceous character of the charge. This result is in agreement with the fact that a good deal of iron and manganese remained unreduced.

The *phosphorus* and *manganese* are low and have already been referred to when dealing with the slag.

Sulphur.

The sulphur is high (0·241 per cent), and renders the steel quite unfit for use. It must be remembered that the charge was exceptionally high in sulphur (0·347 per cent), sufficient to have rendered the production of a good steel a matter of great difficulty by any process.

As I have already shown, when discussing the slag, as much as 17 per cent of the sulphur in the charge has got into the steel and this is, I believe, a much higher proportion than usually gets into pig iron smelted in a blast furnace, though I have no actual records dealing with so sulphurous a charge. It is probable that this proportion would have been considerably reduced if the slag had been made more basic as might have been done with advantage.

Turning once more for the sake of contrast to the experiments at Darfo in which the ore was rich and pure and the charge contained but little sulphur, we get the following figures :—

No.	Percentage of sulphur in charge	Percentage of sulphur in the iron produced	Percentage of sulphur in charge retained in the iron produced
A ...	·041	·073	77·61
B ...	·041	·062	63·71
C ...	·040	·046	43·62
D ...	·041	·065	69·48
E ...	·041	·059	52·14

Here we see that with a low sulphur charge the greater part of the sulphur is retained in the iron, a result which differs from that of Trial B and from the results usually obtained in blast furnace practice and more in accordance with what obtains in an open-hearth process.

So far as the results obtained at Darfo and from Tria
B are a guide, it would seem that when the ore is low i
sulphur the greater portion of the sulphur passes into th
iron or steel, but the percentage in the latter is low
When the ore is high in sulphur a much smaller propor
tion of it passes into the iron or steel, but the percentag
in the latter tends to be high. It would be interesting t
know what occurs between the limits of these experi
ments as most of the ores of commerce lie between them

Fortunately it does not appear to be a difficult matte
to remove a good deal of the sulphur which is reduce
with the iron, and the process which Stassano adopts i
to add calcium carbide to the bath of metal after th
removal of the slag. The reaction which is supposed t
take place is—

$$CaC_2 + S + Fe = CaS + FeC_2.$$

There is no doubt that the addition of carbide does ver
materially reduce the percentage of sulphur and the ex
tent of the reduction appears to be chiefly a question c
time.

In Trial B, 5 Kg. of carbide were added to the bat
immediately after tapping the first slag, but it is ver
doubtful if this served any useful purpose as it does no
appear to have passed any of the sulphur from th
already smelted iron into the second slag, the percentag
of sulphur in the two slags being about the same. Afte
the second slag was tapped, 10 Kg. of carbide were adde
to the bath and left to act for 40 minutes before tappin
the metal. The result is shown by the following analysi
of the metal tapped :—

Metal tapped—Mild Steel—Sample B_7.

Carbon	...	0·232 per cent.
Silicon	...	0·037 „
Sulphur	...	0·124 „
Phosphorus	...	0·015 „
Manganese	...	0·220 „

The analysis of sample B_3 taken from the bath before the addition of the carbide showed that it contained 0·241 per cent of sulphur and the action of the carbide reduced this to 0·124 per cent, a reduction of nearly 50 per cent.

The result is not so good as was expected and the steel was found to be red short. In Major Stassano's opinion the metal was tapped a little too soon and that had it remained a little longer in the furnace, the sulphur would have been reduced very much lower. With this opinion, I agree for reasons which I shall refer to in connection with Trial C. I may also note that at the time of the experiment the amount of sulphur in the ore and the probable amount remaining in the metal before the addition of carbide had been under-estimated. Major Stassano estimated that the sulphur in the bath would be about 0·12 per cent and that by the treatment with carbide it would be reduced to about 0·06 per cent, instead of which the amount in the bath was 0·241 per cent and this was reduced to 0·124 per cent. Further I am not satisfied with the samples taken and I do not think that the bath was sufficiently stirred before tapping the mild steel to render the metal uniform; in fact, it was not properly stirred at all, but only rabbled to stir up the carbide slag. This is borne out by the fact that of several blacksmiths' tests made at the works from the ingots, etc., cast, some were much less red-short than others, and it is probable that the amount of sulphur present in the metal was on the average decidedly less than 0·124 per cent. This view also agrees with the fact that an analysis of one of the small test pieces showed only 0·08 per cent of sulphur, and with the fact that the metal which remained in the bath and was used for Trial C was found to contain only about 0·052 per cent of sulphur, after slightly longer contact with the carbide slag.

As regards the carbon, also, sample B_7 is probably low, the average of three samples being $C=0·301$.

The final result of the trial as regards the production

of mild steel is that the composition aimed at was satisfactorily obtained except in regard to sulphur which was too high. Considering the high percentage of sulphur in the charge, this ought not to be wondered at. The process is, however, in my opinion, capable of dealing even with such a sulphurous ore and of eliminating the sulphur to the extent required for a first class steel; and I am satisfied that this would have been actually achieved in Trial B if the metal had been allowed to remain a little longer in the furnace in contact with the carbide slag.

RESULTS OF TRIAL C.

Analyses made from one of the large ingots (C_4) produced in this trial gave the following results:—

	Ingot C_4. Bottom-outside.	Ingot C_4. Top-centre.	Ingot B_7.
Carbon ...	0·706	0·716	0·232
Silicon ...	0·207	0·207	0·037
Sulphur ...	0·053	0·050	0·124
Phosphorus ...	0·028	0·033	0·015
Manganese ...	0·411	0·390	0·220

Alongside, I have placed the analysis of Ingot B_7 as representing the bath of metal from which C_4 was produced by the addition of pig iron.

The intention was to produce a steel containing 0·6 per cent of carbon, but as the loss in the slag was greater than estimated, the amount of metal in the furnace was actually less than that for which the pig iron added, *viz.*, 15 Kg., was calculated. Taking the following figures as revised by the aid of the analyses subsequently made, we find that the total output of metal from the charge (allowing for loss in slag) should have been about 200 Kg. of which 84 Kg. were tapped as mild steel leaving 116 Kg. in the furnace containing 0·301 per cent of carbon.

116 Kg. of steel at 0·301 per cent C = 0·349 Kg. of carbon
15 Kg. of pig iron at 3·8 per cent C = 0·57 „ „
Total 131 Kg. of steel = 0·919 „ „

thus giving 0·7 per cent carbon in the steel, which agrees very closely with the results of analysis.

It will be noticed that the silicon, phosphorus and manganese have all been increased by the addition of the pig iron due doubtless for the most part to impurities in the pig. The carburization of the steel occupied only a little over 10 minutes and the analysis of the steel produced appears to indicate a very satisfactory high grade material.

The most noteworthy feature is the reduction of the sulphur in comparison with the amount present in the mild steel, although it has nothing to do with the method employed for carburizing the steel and must be considered to be due to the further action of the carbide slag between the time of tapping the mild steel and tapping the hard steel, a matter of some 20 minutes. The result seems to show fairly conclusively that from an indifferent ore a very good grade of steel can be produced by this process and that even if the sulphur in the ore is exceptionally high it can be readily reduced to a fairly harmless amount in the steel. Further, it may be noted that the natural result of the smelting process appears to be a mild steel containing not more than 0·3 per cent carbon, and probably less with a richer ore, and that this mild steel can be readily and rapidly converted to a high carbon steel to the extent desired.

PHYSICAL AND MECHANICAL TESTS.

Trial A.

As might be expected, no satisfactory results were obtained from the scoriaceous mass of metal gathered up from the slag pit. Some of the more solid portions were

hammered into half-inch rods and bent over double when cold. While being drawn out, most of these cracked and fractured and the bends tore open more or less. The analysis shows a good deal of sulphur and the mass of the metal was probably considerably oxidised.

Trial B.

The dip sample B_4 was, as might be expected, brittle and practically unforgeable.

Several tests were made from the ingots of mild steel (B_7) produced in this trial. One of the ingots broke in two on attempting to forge it. A portion was sent to Mr. Harbord for analysis, and he observed that it was very red-short and would not forge. A portion of a small ingot was, however, forged into a half-inch bar and several pieces of this were heated to dull redness and quenched in water and then bent over double while cold. In most cases the bends cracked or tore and only one piece bent clean without a crack.

As I have already pointed out, there was probably a pretty large amount of sulphur in this steel and probably its composition was not uniform. At any rate a satisfactory material had not been produced. On the other hand, there is every reason to believe that had the steel been left some time longer in the furnace, the sulphur would have been reduced sufficiently (say to about 0·05 to 0·06 per cent) to have rendered the steel a satisfactory one for many purposes.

Trial C.

The steel forged well and appeared to be quite sound and easily worked.

A piece was drawn out to a ¾-inch hexagonal bar for a small hand drill or gad, sharpened and tempered, and appeared to act well.

Another piece was drawn out and bent double at a dull red heat without flaw or crack. One end of it was drawn

out to an edge and quenched outright in water. It hardened without a crack and was not touched by a file.

A large ingot (C_4) was sent to Mr. Harbord for analysis and examination and he has informed me that it forged well and appeared all right.

A portion of the ingot was forged into a bar and sent to Messrs. Kirkaldy & Sons, London, to be tested. Their report is as follows:—

Test No. Q. Q. 432.

Description	... Forged bar C_4 290. 1¼″ diam.
Original diameter (turned)	... 0·798 inch.
Original area	... 0·500 sq. inch.
Elastic stress per sq. inch..	51,800 lbs. = 23·2 tons.
Ultimate stress	... 110,000 „ = 49·1 „
Ratio of elastic to ultimate stress	... 47·1 per cent.
Yield point by drop of steel-yard	... 23·7 tons per sq. inch.
Contraction of area at fracture	... 17·4 per cent.
Extension { in two inches..	15·0 „
Extension { in three „	13·3 „
Extension { in eight „	10·1 „
Appearance of fracture ...	8 % silky; 92 % granular.

Test No. Q.Q. 433.

One half of the bar C_4 290 was subjected to 12 blows from weight of 100 lbs, falling 5 feet without breaking. The bar was reversed after each blow. Greatest total deflection—0·24 inch.

Another portion of the ingot—C_4 was forged into a 1″ hexagonal bar and sent to me by Mr. Harbord. As an additional test I asked Mr. Bullen, Superintendent of the Ooregum Gold Mining Company on the Kolar Gold Field, to have the bar made into drills and tried in a rock-drill

in comparison with the drill steel being used in the mine which is considered to be of good quality. Mr. Bullen kindly arranged to do this and the results are given below.

The bar of electric steel C_4 was made into three jumpers sharpened and tempered. The holes were bored in a cross cut in hard tough hornblende schist. The average air pressure was 50 lbs.

Electric steel.—1st Trial.

No. of Jumper.	Depth drilled.	Time.	Remarks.
1	2½ inches	10 minutes	Edge bent.
2	8 „	5 „	Edge worn.
3	7 „	7 „	
Total	17½ „	22 „	= 0·8 in. per minute.

Electric steel.—2nd Trial.

No. of Jumper.	Depth drilled.	Time.	Remarks.
1	9 inches	5 minutes	Edge broken.
2	5 „	3 „	Edge worn.
3	1 inch	2 „	Edge broken.
Total	15 inches	10 „	= 1·5 in. per minute.

Steel used in mine.

No. of Jumper.	Depth drilled.	Time.	Remarks.
1	3 inches	11 minutes	Edge worn.
2	7 „	7 „	
3	7 „	8 „	
Total	17 „	26 „	= 0·65 in. per minute.

The above comparison is, I think, not unfavourable to the electric steel especially in view of the fact that there had been no serious intention of making a steel specially suited for this class of work and also in view of the fact that the smith who made the jumpers was not used to this particular steel and could probably have considerably improved the temper with further experience.

SUMMARY OF RESULTS.

The ore used for the trials was of poor quality and contained an exceptionally high proportion of sulphur, so much so that the production of a first class steel from it by any process would be a matter of considerable difficulty.

The ore when made into bricquettes with charcoal and flux was smelted without hitch or difficulty and the labour employed was practically unskilled. It is to be noted that the ore trials were made alternately with the smelting of steel from scrap, the change from one to the other being made without loss of time and without any alteration of the furnace and its accessories, which speaks well for the ease and simplicity of operation of the furnace.

In spite of the impromptu nature of the trials, the steels produced must be regarded as on the whole satisfactory from an experimental point of view. The mild steel first produced agreed very closely with the product which was intended to be produced except in regard to sulphur, and I have shown reason for believing that had the sulphur present in the bath not been underestimated and had the steel been allowed to remain a little longer in the furnace, this fault would have been rectified and the product quite satisfactory.

Trial C shows that from the material produced by the primary smelting operation a high carbon steel can be made in a very short time and with considerable accuracy, and the mechanical tests of this steel show that it possesses very considerable merit.

The experiments appear to me to go a good way towards removing the objections raised in the case of the Darfo experiments, *viz.*, that the ore used was of exceptional purity and that a steely product of considerable purity would naturally result from any sort of smelting operation and that the results formed no sort of criterion as to the value of the process in the case of the varied

and much less pure ores of commerce. The present trials deal with an ore which errs on the side of impurity, although I could have wished that it had contained more phosphorus. I have no doubt, however, that even a large percentage of phosphorus would be readily eliminated with a basic slag.

The product of the furnace—especially in Trial C—is something more than merely a steely iron and must, I think, be regarded as a genuine steel of very fair composition and character and suitable for commercial use. The composition of the steel appears to be easily under the control of the operator, given a little experience with any particular grade of material, and if anything, more under control than is the product of the usual steel-smelting operations.

Admitting, then, that steel of a desired grade can be produced direct from ore by this process, the next question for consideration is the cost of production. It is obviously of little use to consider in detail the cost of production at Turin from the particular ore used at the trials. What is wanted is the cost of production in Mysore from the ores which are there available, and this is a subject of extreme difficulty in view of the scanty data to hand and must involve many assumptions.

In attempting an estimate, the following points have to be taken into account:—

1. Character and amount of ore available.
2. The supply of charcoal and its cost.
3. The supply of fluxing material and its cost.
4. Crushing and magnetic concentration of the ore and manufacture of bricquettes.
5. The supply of electric energy and its cost.
6. The costs of smelting.
7. The character and sale of products.

PART II.

MATERIALS AND COSTS IN MYSORE.

I. CHARACTER AND AMOUNT OF ORE AVAILABLE.

The Mysore State has long had a reputation for possessing unlimited supplies of very high grade iron ore, a reputation based partly on the evidence of a once widely spread native iron-smelting industry and partly on the reports of observers who have met with numerous large outcrops of highly ferruginous-looking material. Detailed evidence as to the extent and value of the ore bodies from a commercial point of view is still in a very preliminary stage and is somewhat conflicting. I will confine the present remarks to two areas which have been examined somewhat more carefully during the past two years by some of the officers of the Geological Survey, one of which is in the neighbourhood of Malvalli in the Mysore District and the other embraces the Bababudan Hills in the Kadur District.

THE MALVALLI AREA.

This is in close proximity to the Cauvery Falls where the present Electric Power Station is located and which, on account of the supposed large supply of water power, has naturally attracted the attention of speculators and others. The question of the water power available is discussed in another section.

As regards the iron ores, it has from time to time been stated that they are of very high grade and exist in large, if not unlimited, quantity. An examination of the area by Mr. Jayaram, Assistant Geologist(1), failed to reveal the existence of any considerable body of high grade ore, and this has been confirmed subsequently by Mr. H. K. Slater, Assistant Geologist.(2)

(1) Records of the Mysore Geological Department, Vol. VI, Part II.
(2) „ „ „ „ „ VIII, pp. 16 and 61.

One vein of rich magnetite-hæmatite ore was located about three-fourths of a mile west of the Bluff at Sivasamudram and runs northward for about half a mile. The maximum width of the vein is three feet and the average width about one foot. At a few feet below the surface it becomes mixed with quartz, so that the quantity of rich ore available is insignificant—probably not more than 1,000 tons or so. One sample of the ore (H_9/521) gave 56·48 per cent of iron and another 59·91 per cent. There are several other small veins of less importance a few miles to the east of this and to the south of the village of Halagur.

Mr. Slater also observed several runs of quartzose rocks containing magnetite on which there were some shallow old workings presumably made by the native smelters in former times. After a brief inspection of some of these I decided that it would be worth while to obtain some fairly large samples and test them. A number of samples were crushed by Mr. Slater and the magnetic portion extracted with a horse shoe magnet with the following results:—

Sample.	Magnetic material.
H_9/633	37·68 per cent.
H_9/634	72·49 „
H_9/188	66·12 „
H_9/251	60·92 „
O/260	44·32 „

These tests are not very satisfactory and can be regarded only as a very rough guide. A certain amount of the hypersthene present comes up with the magnet and also some quartz containing specks of iron ore. In some cases the tailings carry a good deal of iron probably in the form of hæmatite. The samples were crushed and concentrated dry.

A somewhat more careful test was made with a large sample No. O/261 obtained by deepening a number of old workings on two runs of ore extending for a couple

of miles south of Byadarhalli. In this case the separation was done under water.

100 gms. of ore, which had been passed through a 30-mesh screen, were taken and sieved through a 60-mesh screen.

From the material remaining on the 60-mesh screen 27·02 gms. of magnetic concentrate (A) were obtained.

From the balance which passed through the 60-mesh 30·2 gms. of magnetic concentrate (B) were obtained.

Total 57·22 gms. magnetic concentrate.

The concentrate (A) was then crushed and passed through 60-mesh and again treated with the magnet yielding 23·37 gms. magnetic concentrate.

The non-magnetic material from which (A) was separated was likewise passed through a 60-mesh and yielded 1·38 gms. magnetic concentrate.

The total yield after passing a 60-mesh screen was therefore 54·95 gms. (23·37 + 1·38 + 30·2)

This 54·95 per cent of the ore was found to contain 66·37 per cent of iron.

It would probably not pay to crush the whole of the ore to 60-mesh; and if it were crushed through 30-mesh, it would give about 57 per cent of concentrate containing about 62 per cent of iron.

If, in addition, the coarser concentrate only were re-crushed, we should get a total of about 53 per cent of concentrate containing about 66 per cent of iron.

It is difficult from such a cursory examination to say how far these figures represent results which could be obtained on a large scale, but I am inclined to think that large quantities of ore could be obtained yielding one ton of concentrates, containing 65 per cent of iron, for each two tons of ore.

Cost.—The two beds of ore from which sample O/261 was taken are each about 10 to 15 feet thick and are steeply inclined.

At works in the immediate vicinity the ore ought not

to cost more than from 3 to 3/6 per ton or 6 to 7s. per ton of concentrates. If to this we add the cost of crushing and concentrating as given by the Gröndal Kjellin Co. for a 50 per cent ore in Sweden, *viz.*, 3/8, we obtain a cost of about 10s. per ton of concentrates.

It is obvious that the ore is neither very rich nor particularly inexpensive, and as to the quantity available no sort of estimate could be given without extensive prospecting work. I should estimate that there would be no difficulty in getting, say, a million tons and probably several times this amount.

Various other ore bodies, also of low grade, occur in the Malvalli area, but the available information about them is too indefinite to permit even of rough estimates as to their quantity and value. I am rather of opinion that the estimate which I have given above should be regarded as a minimum, and that should it be necessary for the purpose of extensive operations to obtain larger supplies of ore, these would have to be brought from varying distances thereby considerably enhancing the cost of the concentrates which might easily rise to 12 or 15s. per ton even with a well-equipped system of transport.

THE BABABUDAN AREA.

The Bababudan Hills have likewise been remarked upon from time to time for their richness in iron ore, but until last year no attempt had been made to investigate the extent or value of the ore.

The hills form a chain somewhat in the shape of a nearly closed horse-shoe with the toe to the east and the gap in the heel to the west. The Somavahini River flows out through the gap after draining the Jagar valley, which lies within the horse-shoe. From east to west the horse-shoe has a diameter of about 14 miles and from north to south of about 12 miles, the distance round the main chain of hills being about 40 miles.

During the earlier part of 1908, Mr. Slater surveyed

the northern limb of the horse-shoe and Mr. Sampat Iyengar the southern limb, and a considerable amount of information was obtained as to the distribution of the iron ores, of which reports will be found in Records Vol. VIII.

The work done shows that the whole of the upper portion of the chain of hills is formed of a series of iron ores, of which there are many beds with intervening beds of ferruginous material which are stated to be of a clayey nature. The series of iron ores appear to be several hundred feet in thickness, of which a considerable proportion is occupied by the more compact beds of ore which outcrop in parallel lines running round the steep outer escarpments of the chain. The beds dip inwards towards the Jagar valley at angles of from 30° to 50°, but on the wide toe of the horse-shoe formed by the eastern portion of the chain the dips are much more gentle, usually not exceeding 20°. The ores are very varied in character; the beds in the lower portion of the series appear to be largely composed of magnetite and quartz with some hæmatite; in the intermediate portion, of hæmatite and quartz with some magnetite, while in the upper portions there is comparatively little quartz and the ore is largely hæmatite with some limonite and with laterite modifications.

From a number of samples collected from the north and south limbs of the horse-shoe, both of the Assistant Geologists mentioned above draw the conclusion that there is no very great quantity of rich ore available or of ore which it would pay to extract for smelting purposes. This conclusion is, I think, somewhat premature and is drawn merely from the assays of average samples taken from the escarpment outcrops.

A large number of such samples taken by Mr. Slater from the northern escarpment gave an average of 38 per cent of iron, and samples taken by Mr. Sampat Iyengar from the southern and eastern escarpments gave

an average of 42 per cent iron. These ores are therefore not rich and their possible utility depends on their capability of being cheaply concentrated. A good deal depends on the relative proportions of magnetite and hæmatite, and this point has not been determined, and there is little to be gained by discussing the matter with the information at present available.

On the other hand, some outcrops were found which gave results high in iron. One of these from Virupakshikan Peak (△4099) gave on analysis 68·12 per cent of iron. This is from a surface layer 10 to 15 feet thick, but apparently of no great lateral extent. In another case two beds, a little to the east of Attigundi Travellers' Bungalow, which outcrop for a mile and a half with an average thickness of 6 yards, gave on analysis 65·54 per cent of iron with 10·55 per cent of insoluble residue.

Another bed, one mile south of △6052, was traced for about a mile with a thickness of 4 to 5 feet and the sample yielded 69·23 per cent of iron.

It is obvious, therefore, that there are some considerable items of rich ore to be taken into account, though it is necessary to guard against the inference that the beds are uniformly of such high grade throughout for reasons to which I shall refer presently.

In addition to the foregoing observations I myself paid a short visit to the Bababudans in May 1908 and examined some of the ores in the neighbourhood of Kalhattigiri on the eastern end of the chain of hills. The ore series is here from 2 to 3 miles in width from east to west and the area examined was some 9 or 10 square miles over the whole of which iron ore exists, practically at surface, with a thin covering of soil and grass over the greater portion. A good deal of the ore exposed appeared to be of fairly high grade and composed chiefly of hæmatite with some limonite. In a few places the ore was banded with quartz and contained a good deal of magnetite.

Examination of some road cuttings and some trial pits which I had sunk showed that the better-looking ores formed a surface crust usually some 3 to 4 feet in thickness and that underneath this crust the ores were softer and stained or banded with ochre. This harder crust is not a separate bed, but forms on the outcropping surfaces and edges of the beds (which are lying fairly flat) and on the vertical faces of scarps.

Analysis shows that the crust contains more iron and less water and alumina than the material immediately below, and it would seem that whatever the previous history of the formation of the hæmatite ores may have been, the more recent effects of surface weathering had caused a slight concentration of iron and diminution of alumina in the surface layer. As regards the combined water, this is no doubt due to sub-surface soakage causing hydration and as the surface gets denuded, re-crystallization takes place in the surface crust with loss of some of the water already present.

The following table shows the analyses of some of the samples collected :—

SAMPLES OF IRON ORE.

Number of sample		S_2 477	S_2 479	S_2 493*a*	S_2 493*b*	S_2 493*c*	S_2 495
		%	%	%	%	%	%
Moisture at 100° C.	...	0·5	1·49	0·36	0·52	1·10	0·44
		Results on ores dried at 100° C.					
Water (H_2O)	...	4·06	8·34	6·09	4·98	9·94	4·39
Ferric oxide (Fe_2O_3)	...	90·65	78·08	82·79	84·39	78·83	91·79
Ferrous oxide (FeO)	...	0·98	0·57	0·54	0·67	0·27	1·12
Manganese oxide (MnO)	...	Trace	1·04	0·08	Trace	0·13	Trace
Alumina (Al_2O_3)	...	3·03	6·56	9·82	7·95	6·99	1·98
Magnesia (MgO)	...	0·28	0·51	0·26	0·40	0·35	0·36
Lime (CaO)	...	0·049	0·05	0·13	0·09	0·08	0·09
Silica (SiO_2)	...	0·76	3·63	0·77	2·17	1·50	1·32
Phosphoric anhydride (P_2O_5)	...	0·11	0·098	0·13	0·12	0·24	0·16
Sulphur trioxide (SO_3)	...	0·085	0·13	0·118	0·06	0·12	0·067
Total	...	99·904	99·008	100·728	100·83	98·45	101·277
Metallic iron (Fe)	...	64·22	55·11	58·37	59·59	55·39	65·11
Phosphorus (P)	...	0·048	0·044	0·057	0·052	0·105	0·069
Sulphur (S)	...	0·034	0·052	0·047	0·024	0·048	0·027

NOTES.

No. S_2/477. This is a surface sample from the top of a small hill (△5610) 1½ miles north-west of Kalhattigiri (△6155). The southern scarp of the hill—about 50 feet in height—appears to be all of similar stuff, and it looks as though the whole hill was solid ore of this character; but as I have pointed out, the material in the interior would probably be found to be softer and somewhat less rich. Rather similar-looking material extends from this point along the scarp running W. N. W. for 1½ miles, the scarp—which is at right angles to the bed of ore—being in places 30 feet high. A road cuts through this about three-quarters of a mile W. N. W. of △5610 and shows that the more solid crust is there only about 3 feet thick, below which a face of 10 feet of softer banded ore is exposed.

No. S_2/479 is a sample taken vertically down this 10 feet of softer ore, and the analysis shows a diminution in the iron with increase of water, alumina and silica. This is the least favourable sample of those which have been analysed and it contains 55 per cent of iron.

No. S_2/493*a*. This is from a trial pit ¼ of a mile north-west of the bungalow on hill △5590. The pit was 9 feet deep and the sample was taken vertically down the pit from top to bottom.

No. S_2/493*b*. A sample from the outcrops round about the above pit. It is slightly better than the foregoing, but the difference between the surface crust and the average for a depth of 9 feet is not very marked. There is a large spread of this ore to the north of the pit.

No. S_2/493*c*. From a pit 3 furlongs north-east of △6155—8 feet deep. Sample from top to bottom of pit.

No. S_2/495. From a pit 3 furlongs N. N. E. of above—sample taken from top to bottom of pit for a depth of 7 feet. The result is remarkably high grade and shows that in places the surface enrichment may extend to a considerable depth.

Quantity of ore.

In none of the pits was any marked change noticeable towards the bottom and this, taken in conjunction with the appearance of some of the scarps which show ore faces up to 30 feet in thickness transversely to the bedding, justifies the inference that good ore is obtainable in many places for a greater depth than that reached by the pits.

Judging from a large number of outcrops, I should say that good ores, comparable to those of which the analyses are quoted above, would be found over the greater portion of the area examined, which was some 9 or 10 square miles, and from those outcrops which are more clearly exposed I should regard 3 square miles of good ore as a conservative estimate. On this basis, and without any pretence to final accuracy, it may be convenient to state the nature of the quantity of ore which may be expected to be available.

A square mile is 27,878,400 square feet and a layer 1 foot in thickness gives a similar number of cubic feet. Allowing 10 cubic feet of ore to the ton—a sufficiently liberal estimate—we get 2,787,840 tons per square mile for a depth of 1 foot or 8,363,520 tons for the estimated 3 square miles of area.

If, as I have shown reason to believe, the surface ore extends to a depth of at least 10 feet, we obtain within this depth about 83,000,000 tons.

The outer crust, some 3 or 4 feet thick on the average, consists of richer ores well above the average and this alone would yield some 25,000,000 tons.

To obtain an estimate of much greater accuracy and value it would be necessary to sink a great many pits to a considerable depth and this is, I think, unnecessary at present. It is unfortunately not possible to estimate the quantities available from sampling the outcrops of the beds and taking their geological configuration into account, for, as I have shown reason to believe, the

outcrops are on the whole richer than the material which lies deeper, and this, I think, would be true not only when passing downwards through successive layers or beds, but also when passing inwards from the outcrop along the same bed.

For instance, Sample No. $S_2/493a$ is taken from surface downwards for a depth of 9 feet in a bed which is very much thicker. The bed is slightly inclined to the horizontal and similar results might be expected in pits taken over the greater portion of the outcropping edges, which are fairly well exposed for over half a mile along the strike and for over half a mile at right angles to the strike, and the beds continue for at least another half mile in the same direction just below the surface soil and grass. Taking the dip into account, I estimate that this bed or series of layers has a thickness which is in the neighbourhood of 400 feet, and within the area I have mentioned, *viz.*, half a mile along the strike and 1 mile at right angles to the strike, the volume of the bed would be about 3,000,000,000 cubic feet or say 300,000,000 tons. If all this material was of similar grade to the obliquely exposed edges of the bed or, in other words, if the grade continued uniform along the dip from the exposed edges inwards, then we could reckon on this quantity of good ore from the small area of half a square mile. I have not, however, reckoned in this way, and although I cannot say that a great deal of the bed would not prove to be good and usable ore, I have confined my previous estimates to a crust comprising the outer 10 feet of the bed whether this crust happens to be parallel or oblique to the bed itself.

In the face of these figures and considering the comparatively limited demand which can be expected, it seems unnecessary to speculate on how much ore is obtainable below a depth of 10 feet or how much could be obtained from other parts of the chain of hills which is 40 miles in length.

QUALITY OF ORE.

This is undoubtedly very good, the only objectionable feature being the somewhat high percentage of phosphorus, which varies from 0·044 per cent to 0·105 per cent and is rather more on the average than would be suitable for first class Bessemer ore. This slight excess of phosphorus would create no difficulty in an electric smelting process such as that now under consideration.

The sulphur is low and quite comparable to that in first class ores especially when the high content of iron is taken into account.

Of the slag-forming materials, the alumina is comparatively high while the silica, lime and magnesia are remarkably low on the average, and the amount of lime required for fluxing will apparently be small even allowing for the formation of a comparatively basic slag for the elimination of the phosphorus.

With regard to the percentage of iron, the ores forming the upper crust—which I have roughly estimated at 25,000,000 tons—would appear to contain between 60 and 65 per cent of iron and by calcination this might be raised to an average of 65 per cent with possibly a decrease in the sulphur present. It is rather questionable, however, whether calcination would pay with so good an ore unless it was decided to crush the ore by a dry process.

With regard to the ores immediately beneath the crust which run from 55 per cent to 58 per cent of iron and which contain about 8 per cent of combined water, it might pay to calcine them if the necessary fuel is sufficiently cheap, and for such a purpose the waste gases from the furnaces would be available. It is obvious that calcination must be effected either within the electric furnace or before the ore is introduced, and it is quite possible that the latter would be the more advantageous scheme. In this case the percentage of iron in the calcined ore would be raised to 60 per cent or possibly a little more on the

average and of such ore I have shown reason for believing that at least an additional 60,000,000 tons are quite handy.

Cost of Ore.

The cost of winning the ore will obviously be very small, probably not exceeding 1 shilling to 1/4 per ton for a modest output and less for a large output. The smelting works might be situated at the mines or at the foot of the hills, some 3,000 feet below, the latter alternative being perhaps more desirable; and in either case the cost of ore at the works ought not, I think, to be more than about 1/6 to 2 shillings per ton with proper arrangements for handling. For a small output I would adopt the latter figure.

In view of the larger quantities of ore available in the Bababudans, as well as its cheapness compared with the ores in the neighbourhood of Malvalli and Halagur, I shall confine the following discussion of the supply of power and materials to the former locality.

II. THE SUPPLY OF CHARCOAL AND ITS COST.

The question of the supply of charcoal available and its cost presents many difficulties in attempting to arrive at reliable data.

The following figures quoted in Percy's Metallurgy (Fuel) give the results obtained in a number of European forests. In most cases the figures given are in cubic feet of dry wood; and from the first case quoted, in which the weight is also stated, it is found that about 90 cubic feet of dry wood go to the ton, from which I judge that the figures represent cubic feet of stacked wood. On this assumption the following weights are obtained:—

	Amount of wood produced annually from one acre	
	Volume when stacked	Weight when dry
	C. ft.	Tons.
On the slopes of the Vosges Mountains from forests of beech trees ...	128	1·4
In the Pyrenees—		
A thick wood of beech—20 to 50 years old	2,930	32·5
Wood of beech, alder and nut — 19 years old	1,149	12·7
Wood of beech—12 years old ...	368	4·1
Do 15 to 17 years old ...	907	10·1
Do 12 years old ...	855	9·5
In the Black Forest, Duchy of Baden—		
Wood of hornbeam	...	1·0
Wood of silver fir	...	1·5
In Sweden and Norway—		
Forests chiefly Scotch fir ...	86	0·96

In Sweden, where the forests are used largely for the manufacture of charcoal, the annual growth is stated to average about 25,000 cubic feet per square mile;

12,500 cubic feet per square mile is considered low;

75,000 cubic feet per square mile is the maximum.

Taking 1 cubic foot of dry wood (solid) at 35 lbs., these figures come respectively to—

0·62 tons per acre;

0·31 „

1·86 „

According to another authority the yield of natural forests in Germany is stated to be:—

Oak—high forest, under a rotation of 90 to 120 years, 80 cubic feet per acre=1·25 tons.

Oak—coppice, rotation of 15 to 25 years, 57 cubic feet per acre=0·9 tons.

Silver fir—high forest, rotation of 80 to 110 years, 148 cubic feet per acre=2·3 tons.

I have inserted the weights for the purpose of comparison assuming that the volumes given represent solid wood at 35 lbs per cubic foot.

The figures quoted above for the Pyrenees are remarkably high, and I do not quite understand them: possibly they represent total produce and not annual produce. If they are omitted, the remaining figures tend to show that in Europe from well-managed thick forests of considerable age not more than 1 ton per acre of dry wood can be collected annually. The information is, however, very lacking in precision.

As to conditions in India, a good deal of information is obtainable from a report published in 1883 on the Forest Administration of the Madras Presidency by D. Brandis, F.R.S., C.I.E., Director-General of Forests to the Government of India.

In this report the question of the supply of wood fuel for Madras Railway is very fully discussed.

During the five years ending December 1877 the mean annual consumption of firewood amounted to 71,000 tons at an average cost of Rs. 4-14-3 per ton.

Of 68,420 tons used in 1881 less than one-fifth came from Government forests, the remainder being supplied by private owners, and the report suggests that the private forests had been completely depleted and would be unable to continue to furnish such a supply.

In discussing the probability of the Government forests being able to furnish sufficient fuel under proper reservation and conservancy, Mr. Brandis quotes the following figures as to weight of firewood obtainable per acre.

The Madras Board of Revenue in 1875 stated that fellings in the Salem District had given 12 tons per acre and that reproduction would replace this wood in 12 to 15 years. They estimated, therefore, an annual yield of 1 ton per acre from forest reserves and the cost of producing 1 ton of fuel at 12 annas 5 pies.

Subsequent reports gave the outturn at 4½ tons per acre, which in a 12-year rotation would give an annual yield of ⅓ ton per acre.

In North Arcot, Mr. Sheffield, Deputy Conservator of Forests, cut 1 acre of forest, which had been reserved for 10 years after having been cleared, and obtained 8 tons of engine fuel and 3 tons of small wood. He estimated that with a 15-year rotation the annual yield would be 1 ton per acre. This plot of forest is stated to have been a very good one.

In a larger example Mr. Sheffield reported on the cutting of 1,777 acres in the Mamandur Reserve in which the stock was estimated as equivalent to 1,500 acres fully stocked. The reserve had been cut over in 1869-70, was placed under protection in 1871 and the cutting reported on took place in 1880 to 1882. Seeding trees and all saplings under 4 inches diameter were left and it was estimated that only half the growing stock had been removed.

The total amount of wood obtained by the cutting was 4,952 tons, from which the conclusion is drawn that a growth of 10 years would justify cutting at the rate of 2·8 tons per acre or 0·33 tons per acre per annum in forest fully stocked.

Mr. Brandis finally comes to the conclusion that the annual yield of forest reserves will be between ¼ and ½ ton per acre according to class, the lower yields being obtained in dry districts and the higher in those with moist climate. This estimate, it should be noted, is not intended to express the total annual yield in wood, but only that portion suitable for railway fuel, and excludes the more valuable timbers and the small wood from loppings. It is also noted that the forests are very unevenly stocked and contain many blank spaces.

Plantations.—These have been found to give a much higher yield than natural forests.

Casuarina plantations near the coast of Madras from 5 to 15 years old are stated to yield from 2 to 6 tons per acre.

Colonel Beddone states that, after making due allowances for floods and bad seasons, the average annual yield for casuarina in North Arcot (inland) is 2·85 tons per acre.

Fellings in the Benganur Plantation in the Kolar District of Mysore are stated to indicate an annual yield of 3·36 tons per acre.

Mr. Brandis considers that the average yield might safely be estimated at 2 tons per acre.

On the Nilgiris, at elevations of from 6,000 to 8,000 feet, with good rainfall, the Australian Blue Gum (*Eucalyptus*) is found to thrive remarkably well. Trial cuttings and estimates show that with fully stocked plantations up to 19 years old the annual production of timber per acre amounts to from 11 to 13 tons and Mr. Brandis thinks that the most successful portions, worked as coppice 10 years old, might have an annual yield of 12 tons per

acre. On the average he considers that 6 tons per acre might reasonably be expected in suitable localities.

It is obvious that as regards quantity the productiveness of a suitable area can be largely increased by means of plantations, but on the other hand the wood from plantations costs considerably more than that from reserves of natural forest. No very accurate figures are available on this point, but estimates made by the Madras Board of Revenue are quoted by Mr. Brandis to the effect that wood from natural forests costs a little over one shilling per ton to produce, and from plantations it may be from three to five times this amount. The comparative costs must, however, depend on the rates of seigniorage charged, on whether the plantations are worked by Government or by a company for its own use and on the relative proximity of natural forests and plantations to the smelting works.

Taken as a whole, the foregoing figures tend to show that in well-managed forests in Europe the weight of wood annually available is in the neighbourhood of 1 ton per acre—say 600 tons per square mile—while in the Madras Presidency the annual outturn of wood suitable for fuel varies from $\frac{1}{4}$ to $\frac{1}{2}$ ton per acre.

Prospects of Fuel Supply in Mysore.—On this important question I have consulted Mr. Muttannah, Conservator of Forests with the Government of Mysore, but unfortunately I find that precise information of value is very meagre.

Certain forests from which fuel supplies for Bangalore, for the Kolar Gold Field and for the Railways have been obtained for many years past, were subject to indiscriminate fellings, and definite information as to the quantity of fuel obtained and the methods of felling, conservancy, etc., appears to be lacking. Of recent years, however, certain of these forests have been placed under control and worked systematically, and I have received the following figures from Mr. Muttannah as to the more recent fellings.

KAMASANDRA FOREST, KOLAR DISTRICT.

Year	Area of coupe Acres	Quantity of fuel obtained Tons.
1905-06 ...	... 677	1,756
1906-07 ...	... 775	2,177
1907-08 ...	... 687	1,789½
Total	... 2,139	5,722½

Average yield ... 2·7 tons per acre.

DEVARAYADURGA FOREST, TUMKUR DISTRICT.

Year	Area of coupe Acres.	Quantity of fuel obtained Tons.
1905-06 ...	... 1,116	1,439
1906-07 ...	... 970	1,340
1907-08 ...	... 808	566
Total	... 2,894	3,345

Average yield ... 1·16 tons per acre.

As the period of rotation for the cutting of these coupes is stated to be about 20 years, the annual yield per acre works out at 0·13 and 0·058 tons, respectively, in the two cases.

As the Conservator remarks, these forests have been subjected to heavy and indiscriminate fellings in the past, and these figures are probably much lower than what would be obtained under systematic conservancy. Also these forests are on comparatively poor soil and the rainfall (about 28 inches) is not favourable either as regards quantity or distribution.

Estimates, based partly on some trial fellings, for some

of the better portions of the Kamasandra Forest, appear to indicate that a total output of from 7 to 9 tons per acre might be expected for such portions which, on a rotation of 20 years, would mean an annual yield of about 0·4 tons per acre.

On the whole, these figures agree fairly well with those already discussed in the case of the Madras Presidency.

On the other hand, they do not help us much, as the total quantity of fuel obtainable from these forests is quite small and the forests themselves are very different in character to the heavier jungles of the Shimoga and Kadur Districts, where larger supplies would have to be sought. Unfortunately I have been unable to obtain any figures whatever as to the probable outturn from these larger jungles, as no systematic felling on a large scale has at present been attempted. There can be no question, however, that large areas of these heavy forests would yield on the average more than the best portions of the Kamasandra Forest or, in other words, more than ½ ton per acre per annum, and I do not think that one would err in allowing 1 ton per acre, over considerable areas, for fuel and excluding valuable timber trees. It may be noted that the soil in most of these heavier jungles is good and the rainfall is probably 70 to 80 inches and increases as the jungles of the Western Ghats are approached, and it does not seem unreasonable to assume that the output of fuel might be two or three times as great as in the best portions of the Kamasandra Forest with a poor soil and a badly distributed rainfall of only 28 inches. Mr. Muttannah is of opinion that the yield would be very much more than this but, as there are no data to go upon, it would be unsafe to base any calculations on a very high rate of yield, nor is there any need to strain the point at present.

Assuming that it is possible to make and dispose of 10,000 tons of electrically smelted steel per annum, the amount of charcoal required would be about 3,500 tons,

to make which some four to five times its weight of wood-fuel would be needed, say at the outside 17,500 tons.

If we assume the output of fuel to be 1 ton per acre or 600 tons per square mile, the above supply would be furnished by 30 square miles of good forest.

It is obvious that there will be no difficulty in obtaining the charcoal necessary for an indüstry of these dimensions and if the works were situated in or close to the forest (say near the Bababudan Hills) the collection and transport of charcoal would be comparatively cheap. It is also obvious that it is of little moment whether the output of fuel is reckoned at 1 ton or ½ ton per acre.

But an industry producing 10,000 tons of steel per annum is a small affair and, although there may be no immediate scope for a larger output, it is necessary to take into account future developments which may render a much larger industry possible. In such a case a modern concern which hoped to produce the commoner classes of steel could hardly have an output of less than about 100,000 tons per annum and this would require, on the same basis of calculation, a forest area of 300 square miles. It is obvious that in this case it is of considerable importance whether the forest output of fuel is going to be ½ ton or 1 ton or more per acre.

In the first place it becomes a question whether the supply necessary can be obtained at all or not, and in the second place what it is going to cost. As to the first question I am satisfied that the supply can be obtained from a very fairly compact area even were the yield to fall as low as ½ ton per acre, which would require an area of 600 square miles. I am therefore all the more satisfied as to the supply being obtainable in view of the fact that I consider 1 ton per acre as by no means an unreasonable yield to expect. Beyond this there is the possibility of establishing plantations which would still further increase the supply available, though, of course, at a higher cost.

Cost of Charcoal in Mysore.

Comparatively little charcoal is made in Mysore and the data available for estimating the cost of producing it on a large scale are meagre and uncertain. Mr. Muttannah is of opinion that charcoal could be produced in the large forests at Rs. 10 per ton and delivered on the railway in the Kadur and Shimoga Districts at Rs. 14 to Rs. 18 per ton. The estimate of Rs. 10 is probably low and would mean a very low rate of seigniorage with practically no expense for carting.

In the Bangalore District charcoal is made by contractors and the produce carted to Bangalore, where it is sold for Rs. 30 per ton. This charcoal is made in small pits about 1 yard in diameter, and the following figures have been furnished by a contractor :—

The quantity of firewood required to make 1 ton of charcoal is about 6 tons.

	Per ton of charcoal. Rs.	a.	p.
Seigniorage on charcoal at Rs. 2-8-0 per cart-load of 16 cwts.	3	2	0
Collecting the wood	3	4	0
Average cost of carting wood to place of burning	6	8	0
Labour for burning, etc.	5	2	0
Total ...	18	0	0

In the big forests, such as those of Kadur, Mr. Muttannah is of opinion that the rate of seigniorage would be Re. 1 per ton of firewood; the cost of cutting and stacking the fuel, Re. 1 per ton and the cost of carting, 4 annas per ton mile.

If fairly large heaps or temporary kilns were used, the wood required should not exceed 5 tons and the labour for filling and burning ought not, I think, to exceed Rs. 3

per ton of charcoal. On these figures we would get the following estimate :—

		Rs.	a.	p.
Seigniorage on 5 tons of wood	...	5	0	0
Cutting and stacking of wood	...	5	0	0
Carting to kiln ...	...	3	0	0
Labour for burning ...	...	3	0	0
Total	...	16	0	0

To this must be added transport to smelting works which, if carts were used, at 3 annas per ton per mile up to 20 miles, would come to about Rs. 3 per ton.

On this system very large supply of charcoal could be obtained at a cost Rs. 19 per ton.

This figure might be reduced in many ways. The seigniorage is high and I believe that 12 annas per ton or less is charged in some areas.

Again it might be worth while to put up a modern kiln in which the quantity of wood required could be reduced to 4 tons and in which the labour charges for burning would probably not amount to Re. 1 per ton.

On these conditions the cost would work out as follows :—

		Rs.	a.	p.
Seigniorage on 4 tons of wood	...	3	0	0
Cutting and stacking ...	...	4	0	0
Carting to kiln ...	...	3	0	0
Labour for burning ...	...	1	0	0
Cartage of charcoal to works	...	3	0	0
Depreciation and up-keep of kiln	...	1	0	0
Total	...	15	0	0

In addition, the question of using light surface tramways instead of country carts would have to be considered and this would considerably reduce the transport

charges per ton mile both for wood and charcoal. On the other hand, in using a tramway profitably longer distances would be traversed, especially in the case of the more permanent kiln, so that the final result would probably be more a question of convenience than of reduction of cost.

In the case of a modern kiln the question of recovery of the by-products might come in. Mr. Alfred Chatterton, Director of Industrial and Technical Enquiries to the Government of Madras, in his Administration Report for 1907-08, makes the following statement with regard to some experiments made with casuarina wood from plantations on the Madras coast :—

" By the carbonization of 12,000 tons of wood in iron retorts we expect to obtain—

	Rs.
3,500 tons of charcoal estimated to be worth	70,000
54,000 gallons of wood-spirit worth ...	81,000
540 tons of tar	21,600
700 tons of acetate of lime ...	63,000
Total	2,35,600

That is to say, each ton of wood will yield products worth nearly Rs. 20 and as the cost of growing the timber is certainly less than Rs. 5 per ton it will be evident that there is a large margin for working expenses and for interest and depreciation charges on the capital outlay."

I have also obtained the following figures about the Grondal kiln which is largely used in Sweden for preparation of charcoal with recovery of by-products.

TEST MADE ON GRONDAL KILN FOR THREE MONTHS.

Wood used.—Sodden spruce board edgings saturated with water.

The same edgings were used as fuel in the gas producer, the consumption being 15 per cent of the wood charged into the kiln.

Output of charcoal.—Amounted to 74 per cent of the wood charged, the average output per shift being 2,270 bushels.

By-products.—The average by-products recovered over the three months were—

Raw turpentine	1·36	gallons per cord.
Thick tar	2·36	,,
Tar oil	6·5	,,
Concentrate	289·0	,,

Contents of concentrate—

Acetic acid	5·46	gallons per cord.
Methyl alcohol	2·0	,,

TEST ON GRONDAL KILN FOR 48 HOURS.

Wood used.—Spruce logs, from 10″ diameter downwards, not sufficiently good for saw-mills and thoroughly wet.

Fuel in producer.—Sodden spruce board edgings, the consumption being 7 per cent of the wood charged into the kiln.

Output of charcoal.—Amounted to 85 per cent of the wood charged or 85 bushels per cord.

By-products—

Raw turpentine	1·04	gallons per cord
Thick tar	2·46	,,
Tar oil	13·26	,,
Concentrate	163·2	,,

The cost of labour for this kiln was determined to be per bushel of charcoal $= 0{\cdot}205d.$

If we reckon 1 bushel $= 1\frac{1}{4}$ cubic feet and 1 cubic foot of charcoal $= 12$ lbs., the labour works out about $30d.$ per ton. As wages in Sweden are about 3/6 per shift as against $6d.$ or $8d.$ in Mysore, the estimate which I made above of Re. 1 per ton for labour probably errs on the high side.

It is fairly obvious that, if the by-products thus obtained have anything like the value estimated by Mr. Chatterton, that is to say, if they can be sold within reasonable distance of the kiln, the cost of charcoal to a company making it for its own use would be very materially reduced. As I have no data at hand to go upon, I must leave this possibly important point for the present.

On the whole, indefinite and unsatisfactory as is the information which I have so far been able to obtain, there appear to be sufficient grounds for conviction that in certain localities (such as the Bababudan Hills) the surrounding forests can without any great difficulty furnish a constant supply of charcoal sufficient for the annual production of 100,000 tons of smelted iron or steel at a cost which need not, I believe, exceed Rs. 15, or 20 shillings, per ton and that a considerably larger supply could be obtained at a small additional cost for transport from forests further afield.

For a small supply of some 3,000 to 4,000 tons of charcoal per annum the cost need not, I think, be appreciably higher, for though working expenses and standing charges would be increased transport charges would diminish.

III. THE SUPPLY OF FLUXING MATERIAL AND ITS COST.

Carbonate of lime is fairly abundant in Mysore, either in the form of limestones associated with the Dharwar schists or in the form of superficial deposits of lime kankar—a kind of nodular travertine. So far as I know, there are no large supplies of limestone anywhere near the Bababudan Hills. Small deposits of kankar have been found round about Chikmagalur, but the samples I have seen do not appear to be of high quality and the amount of material available is very limited. Kankar is, however, so widely distributed that it is quite possible that larger deposits may hereafter be discovered in this neighbourhood; the deposits are frequently covered by a thick layer of soil.

The better-known deposits of kankar occur in the Mandya Taluk of the Mysore District and are about 100 miles from the Bababudan Hills. There is no direct railway communication between these places, and the material would have to be brought through Bangalore making a railway lead of something over 200 miles.

The following analyses show the character of the materials which can be obtained from the Mandya Taluk.

ANALYSES OF SAMPLES OF KANKAR.

Number of sample	O/208	O/209	O/210
	Per cent	Per cent	Per cent
Loss on ignition	41·94	42·28	32·00
Silica (SiO_2)	4·58	2·70	24·78
Phosphorus (P)	0·002	0·005	0·004
Sulphur (S)	0·039	0·028	0·048

(*continued*)

ANALYSIS OF SAMPLES OF KANKAR—*concld.*

Number of sample		O/208	O/209	O/210
		Per cent	Per cent	Per cent
Ferric oxide (Fe_2O_3) ...	...	0·96	0·85	1·55
Alumina (Al_2O_3) ...	...	1·51	0·76	4·47
Manganese oxide (MnO)	...	trace	trace	...
Calcium oxide (CaO)...	...	45·60	52·70	25·90
Magnesia (MgO) ...	...	0·38	1·17	10·46

Sample No. O/208 comes from Mardevanhalli and sample No. O/209 comes from Malchakanhalli, both of which places are within 6 miles of the Yeliyur Railway Station. The quality of the kankar is very good and it would make a most excellent flux. Unfortunately these particular deposits do not appear to be very extensive and at present yield only about 20 to 25 tons a year each. The material is sold at Channapatna for the preparation of high class chunam (burnt lime) and fetches a high price--about 10 shillings a ton—which, taking the long railway lead into consideration, would render it rather expensive as flux. If a large quantity was available, no doubt the price would be considerably reduced, but, as I have said, this does not appear to be the case and these deposits may be left out of account as a source of supply.

At Sindlagiri, and on the banks of the Hebhalla River, in the Mandya Taluk, much larger quantities of kankar are to be found, but unfortunately the quality is not good as shewn by the analysis of sample No. O/210, taken from Sindlagiri, and this material must also be passed over as a possible source of supply at any rate on any large scale.

I understand that large quantities of kankar of better quality are imported into Bangalore from Morapur and Samalpatti in the Salem District of the Madras Presidency. This material is said to cost Re. 1 per ton and the

rail charge to Bangalore is Rs. 30 for a 16-ton waggon. This makes the cost at Bangalore Rs. 3 per ton, and if a further Rs. 4 is added for freight from Bangalore to the Bababudans, it ought to be possible to deliver the stuff at the works for Rs. 7, or rather under 10 shillings, per ton.

The following are analyses of two samples. No. R/172 is from Samalpatti and No. R/173 is from Morapur.

ANALYSES OF SALEM KANKAR.

Number of sample	R/172 Per cent	R/173 Per cent
Moisture at 100° C. ...	0·87	0·90
Loss on ignition ...	36·82	35·55
Silica (SiO_2)	9·03	10·93
Ferric oxide (Fe_2O_3) ...	2·35	2·58
Alumina (Al_2O_3) ...	1·08	2·43
Manganous oxide (MnO) ...	0·10	0·074
Calcium oxide (CaO) ...	45·85	43·82
Magnesium oxide (MgO) ...	4·12	2·80
Sulphuric acid (SO_3) ...	0·057	0·061
Phosphoric acid (P_2O_5) ...	0·015	0·05

These materials are of fair quality, but rather too high in silica, a disadvantage which might perhaps be lessened by picking.

Turning now to the limestones of which there are numerous extensive beds or deposits in the State, the nearest to the site of the proposed smelting works at the Bababudan Hills are those which occur close to the edge of the Chitaldrug Schist Belt, a little to the east of Huliyar. This locality is not on the railway and the lead to the nearest Railway Station (Banavar) is about 35 miles and from there to the works there would be a railway lead of about 35 miles. Quarrying the limestone would cost, I think, not more than 2 shillings per ton; cartage for 35 miles at 3d. per ton mile comes to 9 shillings per ton and

railage for 35 miles, at ½d. per ton mile, say, 1s. 6d. per ton. This makes a total cost of 12/6 per ton; but with traction instead of country carts for the road journey it might be reduced by several shillings, and I consider that 10 shillings per ton will be an ample allowance for large quantities and will permit of the exploitation of some other beds rather farther off and a certain amount of selection of material.

The material is rather variable in character and is sometimes rather siliceous. The following analysis (sample No. R. 117) is from a bed near Hulivar of which there is a large quantity available.

ANALYSIS OF LIMESTONE NO. R. 117

Loss on ignition	= 40·62	per cent.
Silica (SiO_2)	= 5·49	,,
Phosphorus (P)	= 0·0014	,,
Sulphur (S)	= 0·035	,,
Ferric oxide (Fe_2O_3)	= 1·77	,,
Alumina (Al_2O_3)	= 0·18	,,
Manganese oxide (MnO)	= 1·06	,,
Calcium oxide (CaO)	= 47·93	,,
Magnesia (MgO)	= 2·89	,,

The percentage of silica is rather higher than desirable, but in other respects the composition is favourable, and on the whole this material should prove a satisfactory flux. Without going further into the matter, I shall take it that flux of this character is available in abundance and that it need not cost more than 10 shillings per ton at the works.

IV. CRUSHING, MAGNETIC CONCENTRATION AND BRICQUETTING.

Crushing.—It may be regarded as one of the essential features of the Stassano process that the ore must be crushed in order that it may be thoroughly mixed with the reducing carbon.

In other furnaces, such as the Heroult, Keller, Girod, Scott-Anderson, etc., which are more or less shaft furnaces and in which heat is generated at the bottom of the charge of ore and carbon, it is possible to avoid the fine-crushing and bricquetting and to use the ore and carbon in small lumps. Doubtless in these cases the reduction of the ore is due partly to the action of CO produced in the hotter part of the furnace by reaction between ore (possibly more or less molten or viscous) and solid carbon. Even in such furnaces it is a question whether the efficiency of the process would not be improved by the bricquetting of ore and carbon in a fine state of division.

In the Stassano furnace, however, owing to the comparatively thin layer of charge on the hearth, heated from above, the greater portion of the CO produced must escape at once without helping to reduce ore, and the reduction must be due almost entirely to the interaction of solid (or viscous) ore and solid carbon, and the rate of smelting must depend very largely on the intimacy of the contact between the two or, in other words, on the fineness of comminution and uniformity of mixture.

Ores which are of such a nature as to require concentration have to be crushed and probably bricquetted, no matter which type of furnace is used, but in the case of ores which do not need concentration a furnace which does not require the ore and carbon to be intimately associated in the form of bricquettes may possibly have some advantage over one which does. So far as I am aware, the products of the two types of furnace are

Cost of Charcoal in Mysore.

Comparatively little charcoal is made in Mysore and the data available for estimating the cost of producing it on a large scale are meagre and uncertain. Mr. Muttannah is of opinion that charcoal could be produced in the large forests at Rs. 10 per ton and delivered on the railway in the Kadur and Shimoga Districts at Rs. 14 to Rs. 18 per ton. The estimate of Rs. 10 is probably low and would mean a very low rate of seigniorage with practically no expense for carting.

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The quantity of firewood required to make 1 ton of charcoal is about 6 tons.

	Per ton of charcoal. Rs.	a.	p.
Seigniorage on charcoal at Rs. 2-8-0 per cart-load of 16 cwts. ...	... 3	2	0
Collecting the wood ...	... 3	4	0
Average cost of carting wood to place of burning ...	... 6	8	0
Labour for burning, etc. ...	... 5	2	0
Total	... 18	0	0

In the big forests, such as those of Kadur, Mr. Muttannah is of opinion that the rate of seigniorage would be Re. 1 per ton of firewood; the cost of cutting and stacking the fuel, Re. 1 per ton and the cost of carting, 4 annas per ton mile.

If fairly large heaps or temporary kilns were used, the wood required should not exceed 5 tons and the labour for filling and burning ought not, I think, to exceed Rs. 3

per ton of charcoal. On these figures we would get the following estimate :—

	Rs.	a.	p.
Seigniorage on 5 tons of wood ...	5	0	0
Cutting and stacking of wood ...	5	0	0
Carting to kiln	3	0	0
Labour for burning	3	0	0
Total ...	16	0	0

To this must be added transport to smelting works which, if carts were used, at 3 annas per ton per mile up to 20 miles, would come to about Rs. 3 per ton.

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Labour for burning	1	0	0
Cartage of charcoal to works ...	3	0	0
Depreciation and up-keep of kiln ...	1	0	0
Total ...	15	0	0

In addition, the question of using light surface tramways instead of country carts would have to be considered and this would considerably reduce the transport

charges per ton mile both for wood and charcoal. On the other hand, in using a tramway profitably longer distances would be traversed, especially in the case of the more permanent kiln, so that the final result would probably be more a question of convenience than of reduction of cost.

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Contents of concentrate—

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Concentrate	163·2	„

The cost of labour for this kiln was determined to be per bushel of charcoal = 0·205*d.*

If we reckon 1 bushel = $1\frac{1}{4}$ cubic feet and 1 cubic foot of charcoal = 12 lbs., the labour works out about 30*d.* per ton. As wages in Sweden are about 3/6 per shift as against 6*d.* or 8*d.* in Mysore, the estimate which I made above of Re. 1 per ton for labour probably errs on the high side.

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Manganese oxide (MnO) ...	trace	trace	...
Calcium oxide (CaO)... ...	45·60	52·70	25·90
Magnesia (MgO)	0·38	1·17	10·46

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Silica (SiO_2)	5·49	,,
Phosphorus (P)	= 0·0014	,,
Sulphur (S)	= 0·035	,,
Ferric oxide (Fe_2O_3)	= 1·77	,,
Alumina (Al_2O_3)	0·18	,,
Manganese oxide (MnO)	= 1·06	,,
Calcium oxide (CaO)	= 47·93	,,
Magnesia (MgO)	= 2·89	,,

The percentage of silica is rather higher than desirable, but in other respects the composition is favourable, and on the whole this material should prove a satisfactory flux. Without going further into the matter, I shall take it that flux of this character is available in abundance and that it need not cost more than 10 shillings per ton at the works.

IV. CRUSHING, MAGNETIC CONCENTRATION AND BRICQUETTING.

Crushing.—It may be regarded as one of the essential features of the Stassano process that the ore must be crushed in order that it may be thoroughly mixed with the reducing carbon.

In other furnaces, such as the Heroult, Keller, Girod, Scott-Anderson, etc., which are more or less shaft furnaces and in which heat is generated at the bottom of the charge of ore and carbon, it is possible to avoid the fine-crushing and bricquetting and to use the ore and carbon in small lumps. Doubtless in these cases the reduction of the ore is due partly to the action of CO produced in the hotter part of the furnace by reaction between ore (possibly more or less molten or viscous) and solid carbon. Even in such furnaces it is a question whether the efficiency of the process would not be improved by the bricquetting of ore and carbon in a fine state of division.

In the Stassano furnace, however, owing to the comparatively thin layer of charge on the hearth, heated from above, the greater portion of the CO produced must escape at once without helping to reduce ore, and the reduction must be due almost entirely to the interaction of solid (or viscous) ore and solid carbon, and the rate of smelting must depend very largely on the intimacy of the contact between the two or, in other words, on the fineness of comminution and uniformity of mixture.

Ores which are of such a nature as to require concentration have to be crushed and probably bricquetted, no matter which type of furnace is used, but in the case of ores which do not need concentration a furnace which does not require the ore and carbon to be intimately associated in the form of bricquettes may possibly have some advantage over one which does. So far as I am aware, the products of the two types of furnace are

Cost of Charcoal in Mysore.

Comparatively little charcoal is made in Mysore and the data available for estimating the cost of producing it on a large scale are meagre and uncertain. Mr. Muttannah is of opinion that charcoal could be produced in the large forests at Rs. 10 per ton and delivered on the railway in the Kadur and Shimoga Districts at Rs. 14 to Rs. 18 per ton. The estimate of Rs. 10 is probably low and would mean a very low rate of seigniorage with practically no expense for carting.

In the Bangalore District charcoal is made by contractors and the produce carted to Bangalore, where it is sold for Rs. 30 per ton. This charcoal is made in small pits about 1 yard in diameter, and the following figures have been furnished by a contractor:—

The quantity of firewood required to make 1 ton of charcoal is about 6 tons.

	Per ton of charcoal. Rs.	a.	p.
Seigniorage on charcoal at Rs. 2-8-0 per cart-load of 16 cwts.	3	2	0
Collecting the wood	3	4	0
Average cost of carting wood to place of burning	6	8	0
Labour for burning, etc.	5	2	0
Total ...	18	0	0

In the big forests, such as those of Kadur, Mr. Muttannah is of opinion that the rate of seigniorage would be Re. 1 per ton of firewood; the cost of cutting and stacking the fuel, Re. 1 per ton and the cost of carting, 4 annas per ton mile.

If fairly large heaps or temporary kilns were used, the wood required should not exceed 5 tons and the labour for filling and burning ought not, I think, to exceed Rs. 3

per ton of charcoal. On these figures we would get the following estimate:—

	Rs.	a.	p.
Seigniorage on 5 tons of wood ...	5	0	0
Cutting and stacking of wood ...	5	0	0
Carting to kiln	3	0	0
Labour for burning	3	0	0
Total ...	16	0	0

To this must be added transport to smelting works which, if carts were used, at 3 annas per ton per mile up to 20 miles, would come to about Rs. 3 per ton.

On this system very large supply of charcoal could be obtained at a cost Rs. 19 per ton.

This figure might be reduced in many ways. The seigniorage is high and I believe that 12 annas per ton or less is charged in some areas.

Again it might be worth while to put up a modern kiln in which the quantity of wood required could be reduced to 4 tons and in which the labour charges for burning would probably not amount to Re. 1 per ton.

On these conditions the cost would work out as follows:—

	Rs.	a.	p.
Seigniorage on 4 tons of wood ...	3	0	0
Cutting and stacking	4	0	0
Carting to kiln	3	0	0
Labour for burning	1	0	0
Cartage of charcoal to works ...	3	0	0
Depreciation and up-keep of kiln ...	1	0	0
Total ...	15	0	0

In addition, the question of using light surface tramways instead of country carts would have to be considered and this would considerably reduce the transport

charges per ton mile both for wood and charcoal. On the other hand, in using a tramway profitably longer distances would be traversed, especially in the case of the more permanent kiln, so that the final result would probably be more a question of convenience than of reduction of cost.

In the case of a modern kiln the question of recovery of the by-products might come in. Mr. Alfred Chatterton, Director of Industrial and Technical Enquiries to the Government of Madras, in his Administration Report for 1907-08, makes the following statement with regard to some experiments made with casuarina wood from plantations on the Madras coast :—

"By the carbonization of 12,000 tons of wood in iron retorts we expect to obtain—

	Rs.
3,500 tons of charcoal estimated to be worth	70,000
54,000 gallons of wood-spirit worth ...	81,000
540 tons of tar	21,600
700 tons of acetate of lime ...	63,000
Total	2,35,600

That is to say, each ton of wood will yield products worth nearly Rs. 20 and as the cost of growing the timber is certainly less than Rs. 5 per ton it will be evident that there is a large margin for working expenses and for interest and depreciation charges on the capital outlay."

I have also obtained the following figures about the Grondal kiln which is largely used in Sweden for preparation of charcoal with recovery of by-products.

Test made on Grondal kiln for three months.

Wood used.—Sodden spruce board edgings saturated with water.

The same edgings were used as fuel in the gas producer, the consumption being 15 per cent of the wood charged into the kiln.

Output of charcoal.—Amounted to 74 per cent of the wood charged, the average output per shift being 2,270 bushels.

By-products.—The average by-products recovered over the three months were—

Raw turpentine	1·36	gallons per cord.
Thick tar	2·36	,,
Tar oil	6·5	,,
Concentrate	289·0	,,

Contents of concentrate—

Acetic acid	5·46	gallons per cord.
Methyl alcohol	2·0	,,

Test on Grondal kiln for 48 hours.

Wood used.—Spruce logs, from 10″ diameter downwards, not sufficiently good for saw-mills and thoroughly wet.

Fuel in producer.—Sodden spruce board edgings, the consumption being 7 per cent of the wood charged into the kiln.

Output of charcoal.—Amounted to 85 per cent of the wood charged or 85 bushels per cord.

By-products—

Raw turpentine	1·04	gallons per cord
Thick tar	2·46	,,
Tar oil	13·26	,,
Concentrate	163·2	,,

The cost of labour for this kiln was determined to be per bushel of charcoal = 0·205*d*.

If we reckon 1 bushel = 1¼ cubic feet and 1 cubic foot of charcoal = 12 lbs., the labour works out about 30*d*. per ton. As wages in Sweden are about 3/6 per shift as against 6*d*. or 8*d*. in Mysore, the estimate which I made above of Re. 1 per ton for labour probably errs on the high side.

It is fairly obvious that, if the by-products thus obtained have anything like the value estimated by Mr. Chatterton, that is to say, if they can be sold within reasonable distance of the kiln, the cost of charcoal to a company making it for its own use would be very materially reduced. As I have no data at hand to go upon, I must leave this possibly important point for the present.

On the whole, indefinite and unsatisfactory as is the information which I have so far been able to obtain, there appear to be sufficient grounds for conviction that in certain localities (such as the Bababudan Hills) the surrounding forests can without any great difficulty furnish a constant supply of charcoal sufficient for the annual production of 100,000 tons of smelted iron or steel at a cost which need not, I believe, exceed Rs. 15, or 20 shillings, per ton and that a considerably larger supply could be obtained at a small additional cost for transport from forests further afield.

For a small supply of some 3,000 to 4,000 tons of charcoal per annum the cost need not, I think, be appreciably higher, for though working expenses and standing charges would be increased transport charges would diminish.

III. THE SUPPLY OF FLUXING MATERIAL AND ITS COST.

Carbonate of lime is fairly abundant in Mysore, either in the form of limestones associated with the Dharwar schists or in the form of superficial deposits of lime kankar—a kind of nodular travertine. So far as I know, there are no large supplies of limestone anywhere near the Bababudan Hills. Small deposits of kankar have been found round about Chikmagalur, but the samples I have seen do not appear to be of high quality and the amount of material available is very limited. Kankar is, however, so widely distributed that it is quite possible that larger deposits may hereafter be discovered in this neighbourhood; the deposits are frequently covered by a thick layer of soil.

The better-known deposits of kankar occur in the Mandya Taluk of the Mysore District and are about 100 miles from the Bababudan Hills. There is no direct railway communication between these places, and the material would have to be brought through Bangalore making a railway lead of something over 200 miles.

The following analyses show the character of the materials which can be obtained from the Mandya Taluk.

ANALYSES OF SAMPLES OF KANKAR.

Number of sample	O/208	O/209	O/210
	Per cent	Per cent	Per cent
Loss on ignition	41·94	42·28	32·00
Silica (SiO_2)	4·58	2·70	24·78
Phosphorus (P)	0·002	0·005	0·004
Sulphur (S)	0·039	0·028	0·048

(*continued*)

ANALYSIS OF SAMPLES OF KANKAR—*concld.*

Number of sample	O/208	O/209	O/21(
	Per cent	Per cent	Per ce
Ferric oxide (Fe_2O_3)	0·96	0·85	1·55
Alumina (Al_2O_3)	1·51	0·76	4·47
Manganese oxide (MnO) ..	trace	trace	...
Calcium oxide (CaO)... ...	45·60	52·70	25·90
Magnesia (MgO)	0·38	1·17	10·46

Sample No. O/208 comes from Mardevanhalli a sample No. O/209 comes from Malchakanhalli, both which places are within 6 miles of the Yeliyur Railw Station. The quality of the kankar is very good and would make a most excellent flux. Unfortunately the particular deposits do not appear to be very extensive a at present yield only about 20 to 25 tons a year eac The material is sold at Channapatna for the preparati of high class chunam (burnt lime) and fetches a hig price--about 10 shillings a ton—which, taking the lo railway lead into consideration, would render it rath expensive as flux. If a large quantity was available, doubt the price would be considerably reduced, but, as have said, this does not appear to be the case and the deposits may be left out of account as a source of suppl

At Sindlagiri, and on the banks of the Hebhalla Rive in the Mandya Taluk, much larger quantities of kank are to be found, but unfortunately the quality is not go as shewn by the analysis of sample No. O/210, taken fro Sindlagiri, and this material must also be passed over as possible source of supply at any rate on any large scale.

I understand that large quantities of kankar of bett quality are imported into Bangalore from Morapur a Samalpatti in the Salem District of the Madras Pre dency. This material is said to cost Re. 1 per ton and t

rail charge to Bangalore is Rs. 30 for a 16-ton waggon. This makes the cost at Bangalore Rs. 3 per ton, and if a further Rs. 4 is added for freight from Bangalore to the Bababudans, it ought to be possible to deliver the stuff at the works for Rs. 7, or rather under 10 shillings, per ton.

The following are analyses of two samples. No. R/172 is from Samalpatti and No. R/173 is from Morapur.

ANALYSES OF SALEM KANKAR.

Number of sample	R/172	R/173
	Per cent	Per cent
Moisture at 100° C. ...	0·87	0·90
Loss on ignition ...	36·82	35·55
Silica (SiO_2)	9·03	10·93
Ferric oxide (Fe_2O_3) ...	2·35	2·58
Alumina (Al_2O_3) ...	1·08	2·43
Manganous oxide (MnO) ...	0·10	0·074
Calcium oxide (CaO) ...	45·85	43·82
Magnesium oxide (MgO) ...	4·12	2·80
Sulphuric acid (SO_3) ...	0·057	0·061
Phosphoric acid (P_2O_5) ...	0·015	0·05

These materials are of fair quality, but rather too high in silica, a disadvantage which might perhaps be lessened by picking.

Turning now to the limestones of which there are numerous extensive beds or deposits in the State, the nearest to the site of the proposed smelting works at the Bababudan Hills are those which occur close to the edge of the Chitaldrug Schist Belt, a little to the east of Huliyar. This locality is not on the railway and the lead to the nearest Railway Station (Banavar) is about 35 miles and from there to the works there would be a railway lead of about 35 miles. Quarrying the limestone would cost, I think, not more than 2 shillings per ton; cartage for 35 miles at 3d. per ton mile comes to 9 shillings per ton and

railage for 35 miles, at ½d. per ton mile, say, 1s. 6d. per ton. This makes a total cost of 12/6 per ton; but with traction instead of country carts for the road journey it might be reduced by several shillings, and I consider that 10 shillings per ton will be an ample allowance for large quantities and will permit of the exploitation of some other beds rather farther off and a certain amount of selection of material.

The material is rather variable in character and is sometimes rather siliceous. The following analysis (sample No. R. 117) is from a bed near Huliyar of which there is a large quantity available.

ANALYSIS OF LIMESTONE No. R. 117

Loss on ignition	= 40·62	per cent.
Silica (SiO_2)	= 5·49	„
Phosphorus (P)	= 0·0014	„
Sulphur (S)	= 0·035	„
Ferric oxide (Fe_2O_3)	= 1·77	„
Alumina (Al_2O_3)	= 0·18	„
Manganese oxide (MnO)	= 1·06	„
Calcium oxide (CaO)	= 47·93	„
Magnesia (MgO)	= 2·89	„

The percentage of silica is rather higher than desirable, but in other respects the composition is favourable, and on the whole this material should prove a satisfactory flux. Without going further into the matter, I shall take it that flux of this character is available in abundance and that it need not cost more than 10 shillings per ton at the works.

IV. CRUSHING, MAGNETIC CONCENTRATION AND BRICQUETTING.

Crushing.—It may be regarded as one of the essential features of the Stassano process that the ore must be crushed in order that it may be thoroughly mixed with the reducing carbon.

In other furnaces, such as the Heroult, Keller, Girod, Scott-Anderson, etc., which are more or less shaft furnaces and in which heat is generated at the bottom of the charge of ore and carbon, it is possible to avoid the fine-crushing and bricquetting and to use the ore and carbon in small lumps. Doubtless in these cases the reduction of the ore is due partly to the action of CO produced in the hotter part of the furnace by reaction between ore (possibly more or less molten or viscous) and solid carbon. Even in such furnaces it is a question whether the efficiency of the process would not be improved by the bricquetting of ore and carbon in a fine state of division.

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Ores which are of such a nature as to require concentration have to be crushed and probably bricquetted, no matter which type of furnace is used, but in the case of ores which do not need concentration a furnace which does not require the ore and carbon to be intimately associated in the form of bricquettes may possibly have some advantage over one which does. So far as I am aware, the products of the two types of furnace are

essentially different; in the one case (shaft furnaces) pig iron is produced and in the Stassano furnace steel is produced, and I am not prepared at present to enter into a discussion of the comparative merits of these two systems of working, for which I do not think sufficient data are yet available.

I will therefore discuss the question of crushing both for ores which require concentration and for those which do not.

I am indebted to the Edison Ore Milling Syndicate, Ld., and the Grondal Kjellin Co., Ld., for the following figures as to cost of plant required and working costs for the crushing, concentration and bricquetting of iron ores, and I have discussed the question personally with the London branches of these firms.

I. Edison Ore Milling Syndicate.

Plant to crush, separate and bricquette 30,000 tons of crude iron ore—say 100 tons per day of 10 hours.

	£
1 Gyratory or jaw crusher to reduce the material to ¾" or less ...	350
1 Rotary dryer to take out the moisture in the crude material as crushed—say an average of 5 per cent ...	450
1 Set of 30" by 6" Edison fine-crushing rolls with belts and bins ...	1,200
1 Set of two vibrating screens ...	225
3 Sets of Edison magnetite magnets ...	700
1 Bricquetting machine with the necessary tanks for preparing the binders, mixers, etc.	750
1 Engine and boiler of 200 h.p. ...	1,100
1 Generator of sufficient capacity to saturate magnets	225
All necessary shafting, pulleys, belts, etc.	225

		£
Conveyors and elevators	.. ...	900
Contingencies	... ...	250
Total at English port	...	6,275
Say roughly	...	£7,000 in India,

of which £4,000 may be allocated to crushing,

£1,500 do to concentrating and

£1,500 do to bricquetting.

From figures obtained and making the necessary allowances for costs of material and labour in India, I get the following estimates of working costs:—

Crushing.—(30,000 tons per year or 100 tons per day of 10 hours.)

Depreciation and repairs of plant—

15 per cent of £4,000 = £600 = 4·8d. per ton.

Power including fuel for dryer with coal at 25/-per ton = 8/-per hour = 9·6d. „

Labour—

1 Engine driver at	...16	pence per day (in Mysore)	
1 Fireman	...10	„	„
1 man for crusher	... 8	„	„
1 „ dryer	... 8	„	„
1 „ rolls	... 8	„	„
1 „ extra	... 8	„	„
Total	...58	pence per day	= 0·58d. per ton

Renewal of plates in crusher and rolls...	2·00d.	„
Sundries	1·00d.	„
Total ...	17·98d.	„
Say ...	18d.	„

The firm calculates 16 pence per ton with European labour and fuel, and it is obvious that the price of fuel in Mysore more than counterbalances the cheap labour.

charges per ton mile both for wood and charcoal. On the other hand, in using a tramway profitably longer distances would be traversed, especially in the case of the more permanent kiln, so that the final result would probably be more a question of convenience than of reduction of cost.

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ANALYSIS OF SAMPLES OF KANKAR—*concld.*

Number of sample	0/208	0/209	0/210
	Per cent	Per cent	Per cent
Ferric oxide (Fe_2O_3)	0·96	0·85	1·55
Alumina (Al_2O_3)	1·51	0·76	4·47
Manganese oxide (MnO) ...	trace	trace	...
Calcium oxide (CaO)... ...	45·60	52·70	25·90
Magnesia (MgO)	0·38	1·17	10·46

Sample No. 0/208 comes from Mardevanhalli and sample No. 0/209 comes from Malchakanhalli, both of which places are within 6 miles of the Yeliyur Railway Station. The quality of the kankar is very good and it would make a most excellent flux. Unfortunately these particular deposits do not appear to be very extensive and at present yield only about 20 to 25 tons a year each. The material is sold at Channapatna for the preparation of high class chunam (burnt lime) and fetches a high price--about 10 shillings a ton—which, taking the long railway lead into consideration, would render it rather expensive as flux. If a large quantity was available, no doubt the price would be considerably reduced, but, as I have said, this does not appear to be the case and these deposits may be left out of account as a source of supply.

At Sindlagiri, and on the banks of the Hebhalla River, in the Mandya Taluk, much larger quantities of kankar are to be found, but unfortunately the quality is not good as shewn by the analysis of sample No. 0/210, taken from Sindlagiri, and this material must also be passed over as a possible source of supply at any rate on any large scale.

I understand that large quantities of kankar of better quality are imported into Bangalore from Morapur and Samalpatti in the Salem District of the Madras Presidency. This material is said to cost Re. 1 per ton and the

rail charge to Bangalore is Rs. 30 for a 16-ton waggon. This makes the cost at Bangalore Rs. 3 per ton, and if a further Rs. 4 is added for freight from Bangalore to the Bababudans, it ought to be possible to deliver the stuff at the works for Rs. 7, or rather under 10 shillings, per ton.

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Number of sample	R/172 Per cent	R/173 Per cent
Moisture at 100° C. ...	0·87	0·90
Loss on ignition ...	36·82	35·55
Silica (SiO_2)	9·03	10·93
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Manganous oxide (MnO) ...	0·10	0·074
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Magnesium oxide (MgO) ...	4·12	2·80
Sulphuric acid (SO_3) ...	0·057	0·061
Phosphoric acid (P_2O_5) ...	0·015	0·05

These materials are of fair quality, but rather too high in silica, a disadvantage which might perhaps be lessened by picking.

Turning now to the limestones of which there are numerous extensive beds or deposits in the State, the nearest to the site of the proposed smelting works at the Bababudan Hills are those which occur close to the edge of the Chitaldrug Schist Belt, a little to the east of Huliyar. This locality is not on the railway and the lead to the nearest Railway Station (Banavar) is about 35 miles and from there to the works there would be a railway lead of about 35 miles. Quarrying the limestone would cost, I think, not more than 2 shillings per ton; cartage for 35 miles at 3d. per ton mile comes to 9 shillings per ton and

railage for 35 miles, at ½d. per ton mile, say, 1s. 6d. per ton. This makes a total cost of 12/6 per ton; but with traction instead of country carts for the road journey it might be reduced by several shillings, and I consider that 10 shillings per ton will be an ample allowance for large quantities and will permit of the exploitation of some other beds rather farther off and a certain amount of selection of material.

The material is rather variable in character and is sometimes rather siliceous. The following analysis (sample No. R. 117) is from a bed near Hulivar of which there is a large quantity available.

ANALYSIS OF LIMESTONE No. R. 117

Loss on ignition	= 40·62	per cent.
Silica (SiO_2)	5·49	„
Phosphorus (P)	= 0·0014	„
Sulphur (S)	= 0·035	„
Ferric oxide (Fe_2O_3)	= 1·77	„
Alumina (Al_2O_3)	= 0·18	„
Manganese oxide (MnO)	= 1·06	„
Calcium oxide (CaO)	= 47·93	„
Magnesia (MgO)	= 2·89	„

The percentage of silica is rather higher than desirable, but in other respects the composition is favourable, and on the whole this material should prove a satisfactory flux. Without going further into the matter, I shall take it that flux of this character is available in abundance and that it need not cost more than 10 shillings per ton at the works.

IV. CRUSHING, MAGNETIC CONCENTRATION AND BRICQUETTING.

Crushing.—It may be regarded as one of the essential features of the Stassano process that the ore must be crushed in order that it may be thoroughly mixed with the reducing carbon.

In other furnaces, such as the Heroult, Keller, Girod, Scott-Anderson, etc., which are more or less shaft furnaces and in which heat is generated at the bottom of the charge of ore and carbon, it is possible to avoid the fine-crushing and bricquetting and to use the ore and carbon in small lumps. Doubtless in these cases the reduction of the ore is due partly to the action of CO produced in the hotter part of the furnace by reaction between ore (possibly more or less molten or viscous) and solid carbon. Even in such furnaces it is a question whether the efficiency of the process would not be improved by the bricquetting of ore and carbon in a fine state of division.

In the Stassano furnace, however, owing to the comparatively thin layer of charge on the hearth, heated from above, the greater portion of the CO produced must escape at once without helping to reduce ore, and the reduction must be due almost entirely to the interaction of solid (or viscous) ore and solid carbon, and the rate of smelting must depend very largely on the intimacy of the contact between the two or, in other words, on the fineness of comminution and uniformity of mixture.

Ores which are of such a nature as to require concentration have to be crushed and probably bricquetted, no matter which type of furnace is used, but in the case of ores which do not need concentration a furnace which does not require the ore and carbon to be intimately associated in the form of bricquettes may possibly have some advantage over one which does. So far as I am aware, the products of the two types of furnace are

Bricquetting with lime.

It has occurred to me, in view of the fact that the ore, flux and charcoal have to be crushed and mixed, that it might be feasible to first calcine the limestone and use the lime as a binding material for making the bricquettes. I tried some bricquettes with concentrated magnetite, charcoal and burnt lime, but they did not cohere very well. No pressure was used as I had no press and I found that the lime was rather stale. Subsequently I tried some of the hæmatite ore of the Bababudans, which I made into balls with the necessary charcoal and freshly burnt lime, and these gave fairly satisfactory results although no pressure was used, and it looks as though bricquettes of this character made in a press would be quite suitable for the Stassano furnace. I have made a rough estimate of the effect of such a process on the cost of bricquetting.

For this purpose I assume that the cost of calcining the limestone before making the bricquettes is balanced by the cost of calcining the same limestone in the electric furnace in the case of the Edison bricquettes made with unburnt lime and a special binder. Probably, however, the former would cost less, especially as waste gases from the furnace would be available for the calcination, but on the other hand, the bricquettes when wetted would take up not only moisture but also some CO_2 which would have to be again driven off in the furnace so that the assumption may not be very incorrect on the whole.

We have then to consider in the case of bricquettes made with limestone and the Edison binder—

(1) the heat required to convert the CO_2 of the limestone to CO,

(2) the amount of carbon necessary to convert one molecule of O, set free from the CO_2, to CO, and

(3) the cost of the special binder.

On the other side there will be the heat required to dehydrate the Ca $(OH)_2$ formed when making the bricquettes from burnt lime.

The heat required to drive off moisture and any CO_2 which may combine with the CaO, I have allowed for in my original assumption.

Assuming a fairly rich ore with 63 per cent of Fe and allowing about 6 per cent loss in the slag, we require 1,700 Kg. of ore to produce 1,000 Kg. (1 ton) of steel.

The ore will require about 12 per cent, say 200 Kg., of $CaCO_3$ for fluxing purposes, and this, if bricquetted with the ore, will contain 88 Kg. of CO_2 or 24 Kg. of C.

This CO_2 will be reduced in the furnace to CO and for each Kg. of C contained will absorb 5,600 calories, while the O set free will combine with 1 Kg. of C (from the charcoal) giving rise to 2,400 calories.

The difference, *viz.*, 3,200 calories, represents the heat required for reduction of CO_2 to CO per Kg. of carbon in the CO_2 to which must be added the cost of 1 Kg. of C for combining with the oxygen.

The cost of this reduction in the furnace for the 200 Kg. of $CaCO_3$ is therefore $24 \times 3{,}200 = 76{,}800$ calories + the cost of 24 Kg. of carbon.

For the other process, in which the limestone is calcined before bricquetting, the 200 Kg. of $CaCO_3$ gives when calcined 112 Kg. of CaO, which, I assume, all combines with water to form Ca $(OH)_2$ and which will have to be dehydrated in the furnace.

The heat of hydration of 1 Kg. of CaO is about 278 calories; consequently $112 \times 278 = 31{,}136$ calories must be supplied in the furnace.

The difference in the heat requirements in the two cases is $76{,}800 - 31{,}136 = 45{,}664$ calories in favour of using burnt lime as a binder.

45,664 calories represent 53 K. W. hours of energy supplied by the furnace or, if we take the thermal efficiency of the furnace at 70 per cent, an expenditure of 76 K. W. hours.

If we take the cost of 1 K.W. hour as 0·10 pence (about £3 per h.p. year), a figure which could very reasonably be expected in Mysore, this means a saving of 7·6 pence per ton of steel, to which must be added the cost of 24 Kg. of carbon consumed in the reduction of CO_2 to CO, or say another 6 pence.

In addition, there will be the saving of the special Edison binder and its preparation, which may be put at, at least, 1/-per ton of bricquettes or 2/4 per ton of steel and perhaps more.

On these assumptions the saving in using burnt lime as a binder comes to 7·6d.+6d.+2/4 or a total of about 3/6 per ton of steel.

Without placing too much reliance on these figures it looks as though the process I have suggested would be quite worth a trial both on the score of expense and of convenience.

V.—THE SUPPLY OF ELECTRICAL ENERGY AND ITS COST.

The first point for consideration is the amount of energy likely to be required, after which the possibility of obtaining such a supply and the cost of obtaining it will be discussed.

According to the figures arrived at below (see pages 105—11) the production of one ton of steel requires the expenditure of some 2,500 K. W. hours of energy supplied electrically. During the progress of the operation about 960 Kg. of CO are produced per ton of steel, which, without taking into account the sensible heat of the gas issuing from the furnace, is capable of yielding 2,304,000 calories on combustion to CO_2. It is obvious that this gas can be utilized, if necessary, for development of power, and I will make an attempt to estimate the probable amount of energy which can be obtained. In order to do so I have to rely on rather indirect evidence.

Modern suction-gas plants using charcoal are said to produce 1 b. h. p. for a consumption of 0·85lbs. (0·4 Kg.) of charcoal. If we consider that all of this charcoal is converted to CO in the producer, the weight of CO used per b.h.p. is 0·933 Kg. In the waste gases from the electric furnace we have 960 Kg. of CO produced per ton of steel and this ought, on the above basis, to furnish approximately 1,000 b.h.p. by means of a gas engine.

In large modern gas engine plants it is considered that about 30 per cent of the calorific value of the gas can be converted to power. This figure is recorded in connection with the use of coal gas or producer gas and does not afford direct evidence to the results which would be obtained with a gas which is almost entirely CO. Results with the latter would be, I should think, if anything, more favourable. However, accepting the 30 per cent basis, and taking 2,304,000 calories as the value of the gas produced per ton of steel, we get—

691,200 calories converted into power, which, as 1 Cal.=0·00156 h.p. hour, gives us 1,078 h.p. hours per ton of steel, a figure which agrees with the previous determination.

In a large plant of over 14,000 h.p. recently erected by the Eschweiler Mining Company at Alsdorf, Aix-la-Chapelle, for utilizing the gas from coke ovens, a series of tests showed that some 6,865 B. T. U. were consumed per I. h.p. hour, or about 1,716 calories. Dividing the 2,304,000 calories available by this figure will give us *1,340 I. h.p. hours* available per ton of steel.

All these results are fairly consistent and go to show that for each ton of steel produced in the electric furnace the waste gases evolved are capable of furnishing about 1,000 h.p. hours, or 745 K. W. hours, of energy.

As it will probably be advantageous to use some of the gas directly for the purpose of drying and dehydrating the ore, we may assume that we have about 500 K. W. hours available for smelting purposes.

If then 2,500 K. W. hours are required per ton of steel, the amount which will have to be supplied by water power will be 2,000 K. W. hours.

For a plant producing 10,000 tons of steel per annum 20,000,000 K. W. hours will be required and, allowing only 7,000 working hours per year, the plant necessary would have to have a capacity of some 3,000 K. W., or say 4,000 h.p., to be derived from water power.

For a plant producing 100,000 tons of steel per annum we may take it that water power would be required to furnish some 35,000 h.p. for smelting purposes, allowing a better load factor than in the case of the smaller plant. We must next consider whether such an amount of power is available or can be obtained in the Mysore State.

For many years past popular imagination has been wont to run riot over the vast amounts of cheap power which are allowed to run to waste in Mysore, but although

it must be admitted that in times of flood several waterfalls are capable of furnishing large amounts of power, it is quite clear that in the drier months of the year the power available is comparatively small and the cost of harnessing and transmitting it by no means inconsiderable. The principal falls to which public attention has from time to time been drawn are—

the Gersoppa Falls in the north-west corner of the State,

the Cauvery Falls at Sivasamudram,

the Hoskan and Kattehole Falls on the Bababudan Hills.

The Gersoppa Falls are about 900 feet in height and for a power scheme probably over 1,000 feet could be obtained. In the drier months of the year there is comparatively little water in the river, but I have no information as to the actual quantity. I have seen the falls in the dry weather and doubt if more than 10,000 h.p. could be obtained throughout the year. This source may, however, be left out of consideration, for the present at least, as the water rights belong partly to the Government of Bombay and further the Government of India have, I understand, a sentimental objection to the use of the falls for power purposes.

The Hoskan and Kattehole Falls have naturally attracted attention owing to their situation on the Bababudan Hills in the midst of the iron ores, and extraordinary estimates of the power available amounting to hundreds of thousands of horse-power have been put forward.

While investigating the iron ores I had a look at these falls in company with Captain Dawes, R.E., Deputy Chief Engineer in Mysore, and the conclusion we arrived at was that neither fall was of any practical importance whatever. The quantity of water in the dry weather is very small and owing to the narrowness and steepness of the stream valleys there is little scope for storage. The

Hoskan Fall might furnish some 200 to 300 h.p. and the Kattehole Fall not more than 500 h.p. throughout the year.

At the Cauvery Falls, there is already a Power Scheme in operation for the development of some 11,000 h.p. all of which is taken up and some of which cannot be guaranteed throughout the year. There is obviously no possibility of any further supply from this source unless storage reservoirs are constructed for conserving some of the excess water which runs to waste during the rainy season. Fortunately such storage works are quite feasible and a very comprehensive scheme has been worked out by Captain Dawes which is capable of furnishing a constant supply of 60,000 h.p. with possibilities of a further increase.

The complete scheme involves the transference of the generating station from the Cauvery Falls to some falls on the Shimsha River, where a head of over 500 feet can be obtained, but even without such transfer it is obvious that the construction of the storage reservoir would permit of the Sivasamudram plant being very largely increased and the transfer to the Shimsha might be deferred until a larger supply of power is actually required.

Up to the present this scheme has not been taken in hand, nor even, I think, very seriously considered, but I have heard of no serious objection to it either on the financial or technical side. Undoubtedly a considerable capital expenditure will be required, but taking into account the fact that a considerable proportion of the energy which will be made available can be sold for power purposes at highly remunerative rates, the scheme appears to afford the State the opportunity of acquiring a very valuable permanent asset in the shape of a large perennial supply of water for the development of power. From the point of view of electric smelting it is necessary that the power should be supplied at a fairly cheap rate, and it is quite certain that this cannot be done if such power

is to be debited with interest charges on a large capital outlay for storage reservoirs, hydraulic works and long transmission lines. If, therefore, any smelting scheme is to be run from this power it is necessary that these charges should be debited elsewhere, and at present there is the opportunity for debiting them to the power which can be supplied to mines, factories, etc., at remunerative rates. As these latter markets cannot be regarded as permanent, it will not be sufficient to merely debit the annual charges to them, but the capital expended should be as rapidly as possible written off and finally wiped out while the more profitable markets are available. It is obvious that for this purpose time is of the utmost importance and the sooner the scheme is put into operation the easier it will be to secure this end and the more profitable. If, on the other hand, the scheme should be deferred until the more profitable markets have disappeared or been otherwise supplied, it is quite certain that it will be impossible to secure a sufficiently cheap supply of energy for smelting or other operations for which cheap power is a *sine qua non*.

As to the rate at which electrical energy could be supplied for smelting purposes under such a scheme, we are hardly in a position, at present, to assign a definite limit. The present plant at Sivasamudram and the transmission lines to Kolar are, I understand, distinctly expensive.

Mr. H. P. Gibbs, Chief Electrical Engineer to the Government of Mysore, informs me that the cost of generating at Sivasamudram is at present about £3 per h.p. year, including interest and depreciation, and to this must be added the cost of transmission. The cost of taking the power from Sivasamudram to smelting works near the Bababudan Hills, a distance of about 130 miles, would probably add another £1-10-0, so that on these figures the cost of energy at the works would be not less than £4-10-0 per h.p. year. There is little doubt that the generating

costs of £3 per h.p. year could be considerably reduced, and statements, which I must take on trust, have been published which go to show that in Canada, Norway and Italy power can be generated at £2 per h.p. year or even less. Doubtless these are favourable cases, but it appears to me that, if the Cauvery Reservoir Project is put through and the general capital charges are borne by a portion of the plant, then the portion of the plant allotted for smelting purposes will stand in a very favourable position indeed and we might reasonably expect to be able to supply energy at the smelting works at £3 per h.p. year, or even less in the future if a fair amount of the Cauvery Power continues to be disposed of at remunerative rates for power purposes.

Such a figure as £3 per h.p. year does not, of course, include anything in the shape of profit or remuneration to the Mysore State from the sale of the power, but it must be remembered that the State does not stand simply in the position of a power-supply company or corporation and has other benefits and advantages to look forward to in connection with the development of a permanent manufacturing industry. There are profits and advantages to be derived from royalties on ores and finished materials, from the sale of large quantities of charcoal and the opening up of forest areas and exploitation of timber, from the sale of power for the machinery and plant which will be required for treatment of the product of the smelting works, which power could be sold at highly remunerative rates, and finally the general advantages in the shape of employment, wages, etc., consequent on the development of a considerable manufacturing industry. Obviously such a combined scheme as I have suggested is one which could be carried out only by the State, but up to the present there is no indication as to whether it will be taken in hand or not. It is worth while, therefore, to consider whether there are any other sources from which a sufficient supply of power can be obtained

as an alternative or accessory scheme to that outlined above.

I have already shown that the Hoskan and Kattehole Water Falls are practically unimportant, but I have received some very encouraging information from Captain Dawes as to the possibility of developing power in other portions of the Kadur District which he has recently inspected and which are not very far removed from the iron ores of the Bababudans. One of these projects consists in bunding the water of the upper Somavahini valley in the neighbourhood of Malandur and taking the water along the sides of the valley in a pipe to a point above Muthodi where a fall of about 700 feet can be obtained. Captain Dawes estimates that this would give about 5,000 h.p. and that the capital expenditure would not be very large so that in all probability the power would not cost more than from £3 to £4 per h.p. year delivered at the smelting works which would be not more than 15 miles away.

Further down the stream there is a gorge near Hebbe, where the river passes out of the Jagar valley, and here Captain Dawes estimates that a bund might be constructed which would give an additional 20,000 h.p. at even less cost than the previous scheme. It would not, however, be advisable to take the cost at less than £3 per h.p. year. This power would also be within 15 miles of the smelting works.

We have thus the possibility of obtaining at least 25,000 h.p. at a moderate cost within a short distance of the works. Some other sites on the Western Ghats have also been noted by Captain Dawes where further supplies could be obtained, if necessary, up to some 20,000 h.p. at the expense of a longer lead, say some 35 miles, and for which the cost might be put down at £4 per h.p. year on the average. As some of this additional power would be required for power purposes for which a much higher charge would be justifiable, it seems to me that an

all-round estimate of £3 per h.p. year for the energy required for the smelting plant is not unwarrantably low and in the subsequent calculations of working costs I have adopted this figure.

VI. THE COST OF SMELTING.

A—Energy required to smelt 1 ton of steel.

In Trial A the current was supplied to the furnace for altogether 4·75 hours for a calculated output of 97 Kg. of steel which is equivalent to 48·9 hours per ton.

The power of the furnace was, as I have shown, approximately 163·5 K. W. and for 48·9 hours this means a consumption of energy equal to—

8,995 K. W. hours per ton of steel.

In Trial B the current was rather variable and we may take it that on the average it was 750 amperes for 6½ hours and 550 amperes for 1 hour. This works out at a total of 1,298 K. W. hours for a calculated output of 200 Kg. or

6,490 K. W. hours per ton of steel.

These figures are not of much value as direct evidence. In the first trial the furnace was working much below its full capacity and this is indicated by the larger consumption of energy. Even in the second trial the furnace was not, in my opinion, working up to its full capacity.

As regards the consumption of energy, however, the most important factor is the grade of the ore being smelted, and the ore used in the trials was of low grade. There was a great deal of slag to be formed and melted, and with finely crushed and bricquetted material I should judge that the actual reduction of ore was of much less importance, as regards time, than the melting of the various materials. In other words, I incline to the belief that with the same weight of bricquette made from rich ore the output would have been almost proportionally increased without any increase in the time of the whole operation.

This view is rather confirmed by the results of Stassano's experiments at Darfo on the rich ore of Elba.

Taking the various amounts of steel produced in those experiments and the energy consumed, we get the following figures :—

		K. W. Hours per ton of steel.
Experiment	A	4,411
,,	B	5,615
,,	C	4,969
,,	D	3,632
,,	E	3,156

The Elba ore contains 93 per cent Fe_2O_3, and if this is made into bricquettes of the following composition, *viz.*—

Ore	...	100 parts
Charcoal	...	24 ,,
Limestone	...	12·5 ,,

the bricquettes will contain 47·7 per cent Fe. If 800 Kg. of these bricquettes were smelted in the same furnace as used for Trial B (Turin), the bricquettes would contain 381·6 Kg. of Fe; and allowing 6 per cent loss in the slag, the operation would yield some 358·7 Kg. of steel as against the 200 Kg. obtained in Trial B from bricquettes containing only 28·79 per cent Fe.

Assuming for the sake of argument that the smelting operation takes the same time in the case of each of these ores, the consumption of energy in Trial B, *viz.*, 6,490 K. W. hours, would be reduced in the ratio of $\frac{200}{358 \cdot 7}$ in the case of the Elba ore.

In other words, the consumption in the latter case would be $\frac{6,490 \times 200}{358 \cdot 7} = 3,618$ *K. W. hours per ton of steel,* a figure which agrees with the more favourable of the Darfo experiments.

If the ore used contained only 60 per cent Fe and similar bricquettes were used, the latter would contain 43·95 per cent Fe, 800 Kg. of these bricquettes would contain 351·6 Kg. of Fe and allowing 7 per cent loss in the slag,

the yield would be 327 Kg. of steel, which on the same assumption as before would mean—

3,969 K. W. hours per ton of steel.

The foregoing estimates, which on the whole agree with the Darfo figures, are, in my opinion, based on fairly reasonable assumptions, and the consumption of energy ought to be capable of considerable reduction by the use of larger furnaces worked to their full capacity. For the purpose of arriving at a minimum limit I have worked out the following example of the actual heat required for smelting a fairly rich ore such as could be readily obtained in quantity from the Bababudan Hills without any preliminary treatment. It will be seen that the ore collected does not represent the best that might be obtained:

I assume that the dried ore has the following composition:—

Combined water	=	6·00	per cent.	
Fe_2O_3	=	85·70	„	Fe=60 %
Al_2O_3	=	5·50	„	
MgO	=	0·40	„	
CaO	=	0·10	„	
SiO_2	=	2·00	„	
Difference	=	0·30	„	
		100·00		

The *Limestone* used for flux contains—

40 per cent of CO_2 and 60 per cent of slag-forming material.

The *Charcoal* contains—

90 per cent C and 5 per cent slag-forming material.

Further, I assume a loss of 7 per cent of the iron which makes the final yield of metal, which may be regarded as steel, 55·8 Kg. per 100 Kg. of ore. The metal lost in slag amounts to 4·2 Kg. and adds 5·4 Kg. of FeO to the slag per 100 Kg. of ore. As the bricquettes are made up

wet and only partially dried, I estimate that they contain 5 per cent of moisture.

The following will be approximately the composition of the bricquettes :—

Ore	... 100 Kg.
Charcoal	... 24 ,,
Limestone	... 12·5 ,,
Moisture	... 7·0 ,,

To obtain 1 ton (1,000 Kg.) of steel the above quantities must be multiplied by 17·92. So the weights of materials charged will be—

Ore	... 1,792 Kg.
Charcoal	... 430 ,,
Limestone	... 224 ,,
Moisture	... 125 ,,

The *Ore* contains 107 Kg. combined water; 152·3 Kg. slag+96·7 Kg. of FeO, which goes into slag, and 1,000 Kg. of Fe which is recovered.

The *Charcoal* contains 387 Kg. of carbon and 21·5 Kg. of slag.

The *Limestone* contains 89·6 Kg. of CO_2 and 134·4 Kg. of slag.

The moisture in bricquettes=125 Kg. of H_2O.

The total weight of slag is 152·3+96·7+21·5+134·4 =*405 Kg.*

The quantities to be dealt with are therefore—

1,000 Kg. of Fe reduced from Fe_2O_3 and melted;

405 Kg. of slag to be melted;

107 Kg. of H_2O to be driven off, evaporated and raised to 500° C.;

125 Kg. of H_2O (moisture) to be evaporated and raised to 500° C.;

387 Kg. of C burnt to CO=903 Kg. of CO;

89·6 Kg. of CO_2 reduced to CO=57 Kg. of CO;

960 Kg. of CO raised to 500° C.;

89·6 Kg. of CO_2 calcined from the limestone.

I assume with Stassano that the gases leave the furnace at a temperature of 500° C.

For the calculation I adopt the following data gleaned from various sources :—

1 Kg. of Fe reduced from Fe_2O_3 absorbs	1,720	calories (large).
1 Kg. of Fe for melting absorbs ...	350	,,
1 Kg. of slag (basic) for melting absorbs	500	,,
1 Kg. of CO_2 calcined from limestone absorbs	966	,,
1 Kg. of CO_2 reduced to CO absorbs ...	1,526	,,
To raise temperature of 1 Kg. of CO by 1° C. absorbs	0·24	,,
To raise 1 Kg. of H_2O to 100° C. and evaporate it absorbs ...	636	,,
To raise temperature of 1 Kg. of steam by 1° C. absorbs	0·48	,,
To drive off 1 Kg. combined H_2O from ore probably does not exceed ...	500	,,
1 Kg. of C burnt to CO yields ...	2,400	,,

Hence—

1,000 Kg. of Fe reduced from Fe_2O_3 absorbs (1,000 × 1,720)	= 1,720,000	calories.
1,000 Kg. of Fe for melting absorbs (1,000 × 350)	= 350,000	,,
405 Kg. of slag for melting absorbs (405 × 500)	= 202,500	,,
Calcination of 89·6 Kg. of CO_2 absorbs (89·6 × 966)	= 85,553	,,

(continued)

Reduction of 89·6 Kg. of CO_2 to CO absorbs (89·6 × 1,526) -	136,729	calories.
960 Kg. of CO raised to 500° C. absorbs (960 × 0·24 × 500) -	115,000	,,
To drive off 107 Kg. of combined water from ore (107 × 500)	53,500	,,
To raise 230 Kg. of H_2O to 100° and evaporate it (230 × 636)	145,280	,,
To raise 230 Kg. of steam from 100° to 500° C. (230 × 0·48 × 400)	44,000	,,
Total absorbed -	2,852,562	,,
387 Kg. of C burning to CO gives out (387 × 2,400) =	928,800	,,
Difference = net heat required =	1,923,762	,,

As 860 calories = 1 K. W. hour, the energy required per ton of steel produced is *2,237 K. W. hours.*

If we take the thermal efficiency of the furnace at 80 per cent, and with large furnaces working to full capacity it is likely to amount to this, the above figure would require the expenditure of *2,795 K. W. hours.*

In addition, we must not lose sight of the 960 Kg. of CO which is produced and which, if burnt to CO_2, is capable of yielding 960 × 2,400 = 2,304,000 calories, an asset of considerable value, the utilization of which would need careful consideration in any complete scheme.

I have already shown that this may partly be used to generate some of the energy required for smelting. A portion may be used to dehydrate the ore. This would save some 142,096 calories in the furnace equivalent to 165 K. W. hours, or, if the thermal efficiency is 80 per cent, to some *206 K. W. hours*, and would reduce the energy required to about 2,500 K. W. hours per ton of steel. I see no reason why this figure should not be obtained in practice and even somewhat improved upon

in the case of the richer ores. It is interesting to compare with this figure some of the results which have been obtained in smelting for pig iron.

In the experiments with the Keller furnace, conducted for the Canadian Commission, the two trial runs which were made gave, respectively, 3,415 and 1,620 K. W. hours per ton of pig, and Mr. Harbord considers that the mean of these two results would be the most suitable figure to adopt, *viz., 2,517 K. W. hours per ton of pig.*

In the experiments made by the Canadian Government at Sault Ste Marie, the better results work out about *1,700 K. W. hours per ton.*

These figures may be capable of some improvement and taking into consideration the difference in the character of the two operations and the fact that the gases evolved probably take part in the reduction to pig iron, the estimate of 2,500 K. W. hours per ton of steel does not appear to me to be too low.

B—Summary of items of costs.

In collecting these figures I shall keep in view two plants —one comparatively small with an output of about 10,000 tons per annum, and the other moderately large with an output of about 100,000 tons per annum. The products of these two plants would naturally undergo different treatments and be used for different markets. The smaller plant would supply chiefly castings and forgings with some special high grade steels, while the larger would, in addition to these classes of material, have to convert the major portion of its output into the commoner forms of steel with rolled sections.

1. *Ore.*—I have shown that on the Bababudan Hills there is a large quantity of high grade ore which would, I believe, average some 65 per cent Fe with preliminary dehydration by means of some of the gases from the furnaces. Even though my estimate of 25,000,000 tons

of such material may be somewhat in excess of the truth, there can be no question that there is ample material with which to run the smaller if not the larger plant.

I have estimated that this ore could be delivered at the works at from 1s. 6d. to 2 shillings per ton. For the smaller plant I adopt the latter figure and for the larger plant the former. If necessary, a much larger supply of ore can be obtained, which with dehydration ought to average some 60 per cent Fe.

2. *Charcoal.*—I have shown that charcoal may probably be obtained at a cost of 20 shillings per ton without taking the question of by-products into account. It might, however, be safer to adopt 25 shillings per ton for the smaller plant and 20 shillings per ton for the larger plant.

3. *Limestone.*—As I know of no supplies very close to the works, I have allowed 10 shillings per ton for limestone, which ought, I think, to be ample.

4. *Crushing and dehydrating ore.*—My estimate for crushing and drying ore on the lines suggested by the Edison Ore Milling Syndicate was 14 pence per ton. If the ore has to be dehydrated instead of merely dried, the cost would be somewhat increased, and on the whole I think that 2 shillings would be a safe figure for the smaller plant and somewhat less, say 1·5 shillings, for the larger plant.

5. *Crushing limestone and charcoal.*—I have lumped these at 1 shilling per ton for the smaller and 0·8 shilling per ton for the larger plant. The item is quite a small one.

6. *Bricquetting.*—The estimate arrived at, using the Edison binder, was 25·2 pence per ton of bricquettes for about 20,000 tons per annum. For the smaller plant which would require about this quantity, I put the figure at 2·5 shillings per ton and for the larger plant at 2·0 shillings per ton. Some saving may be possible by bricquetting with lime.

7. *Electrical energy.*—This is a point on which further practical information is required, but I have shown some reasons for thinking that the energy required for a 65 per cent ore may be as low as 2,500 K. W. hours per ton of steel, and I shall adopt this figure for the purpose of an estimate. With the 60 per cent ore the energy required would be somewhat increased, but on the other hand, with the larger total consumption and better load factor, the price per unit would tend to be less. In the following estimates I shall retain the same figure for consumption in both cases and also the same price per unit.

Price per unit.—I have already given reasons for thinking that the energy required for smelting purposes might, with a fairly good load factor, be obtained at £3 per h.p. year and possibly even less. £3 per h.p. year is 0·11 penny or 0·0092 shilling per K. W. hour; and I have adopted 0·01 shilling per K. W. hour.

8. *Lining of furnace.*—At Turin, Stassano gives the cost of lining the 1,000 h.p. furnace as £200 and the subsequent costs of re-lining at from ⅔ to ¾ of this. We might thus take the average cost to be £150.

The magnesia bricks cost at Turin £12 per ton, but in Mysore, where there are supplies of magnesite, the cost ought not to be more than £5 or £6 per ton, which would reduce the cost of lining to about £75.

For making steel from scrap the furnace would have an output of some 16 tons per day and the lining is said to last about 22 days. This means an output of over 300 tons per month at a cost for lining of £75 or say *5 shillings per ton of steel.*

For making steel from ore the output of the furnace should be about 5 tons per day and if the lining lasts for 18 days the output would be 90 tons for £75 or about 17 shillings per ton.

For the smaller plant I take 20 shillings per ton as a reasonable figure.

For the larger plant it is obvious that considerably larger furnaces will be required, and I see no reason why they should not be devised. With larger furnaces the proportion of lining to output should be reduced very materially, though I cannot say to what extent. From the above figures, however, I do not think it would be going beyond a reasonable probability to reduce the cost of lining to *16 shillings per ton of steel* for the larger plant, and it is possible that it would be considerably less.

This is evidently a very expensive item and anything tending to reduce the cost of the lining would materially improve matters.

9. *Electrodes.*—In making steel from scrap at Turin the consumption of electrodes works out at about 4 Kg. per ton and the cost at 4 pence per Kg. is 16 pence. To this Stassano adds 24 pence for breakage and waste, making a total of 40 pence per ton of steel.

With a plant for making electrodes at the works and using up the broken and scrap material and with more careful manufacture which would much reduce breakage it is probable that the above figure could be halved, or say 2 shillings per ton of steel.

For the manufacture of steel from ore this figure would require to be multiplied three or four times according to size and output of furnaces, so that we may adopt—

8 shillings per ton for the smaller plant and

6 shillings per ton for the larger plant

as reasonable figures to expect.

10. *Labour for smelting.*—The figures already given for getting and preparing the materials include labour, and we have now to add the labour costs at and about the furnaces.

At Turin Stassano gives the cost of labour for a 1,000 h.p. furnace making steel from scrap as Lr. 4 or 40 pence per ton, the wages being about 4 shillings per man per shift.

In Mysore the wages would be about one-fourth of the above, except in the case of foremen, and probably a few more men would be required. On the other hand, the number of men would be reduced where a number of furnaces were at work.

From these considerations I would put the cost of labour at from 1·0 shilling to 1·5 shillings per ton of steel.

For the manufacture of steel from ore these figures would require to be multiplied two or three times; hence I consider that 4·0 shillings per ton for the larger plant and

6·0 shillings per ton for the smaller plant would be ample to allow.

11. *General expenses.*—For these I allow—

5 shillings per ton for the smaller and

2 shillings per ton for the larger plant.

12. *Management and supervision.*—For this I think it would be sufficient to allow—

5 shillings per ton, or £2,500 per annum, for the smaller, and 1 shilling per ton, or £5,000 per annum, for the larger plant.

13. *Interest and depreciation* on the smelting plant including buildings, cranes and accessories. For the smaller plant we might estimate that a 1,000 h.p. furnace is capable of producing 5 tons per day and is in commission for 20 days per month. This means 1,200 tons per year per furnace, and for an output of 10,000 tons, ten furnaces would be required allowing a margin for accidents.

According to Stassano a furnace costs £2,000, but it is probable that a number could be made at £1,500 or less if the oscillating type were used instead of the revolving type.

The cost of the furnaces would then be about £15,000 and for the buildings, accessories, etc., I would allow £35,000 making a total of £50,000.

Interest and depreciation on the whole of this amount

at 10 per cent would be £5,000 per annum or *10 shillings per ton of steel.*

For the larger plant it would be necessary to use larger furnaces, and they should be considerably cheaper per 1,000 h.p., say £1,000 as against £1,500 in the previous case. Without allowing for increased efficiency in the larger furnaces or reducing the allowance for accidental stoppages, the cost of furnaces for 100,000 tons of steel would be £100,000. It is probable that £50,000 would be sufficient to allow for buildings, accessories and erection making a total of £150,000. As such a large proportion of this represents the furnaces, I would make the rate for interest and depreciation 15 per cent or £22,500 per annum—which is *4·5 shillings per ton of steel.*

C.—Estimates of Cost.

Using the foregoing figures as a basis, we may now consider the detailed cost in three cases, *viz* :—

(1) Ore which after dehydration contains 65 per cent Fe; annual output 10,000 tons of steel.

(2) Similar ore to (1); output 100,000 tons of steel.

(3) Ore which after dehydration contains 60 per cent Fe; annual output 100,000 tons of steel.

For Nos. (1) and (2)—

100 Kg. of the dehydrated ore contain 65 Kg. of Fe. Allowing 6 per cent loss in the slag, the yield will be 61 Kg. of steel, and therefore $\frac{100}{61} \times 1000 = 1{,}640$ Kg. of dry ore will be required per ton of steel.

Taking the composition of the bricquettes at

100 Kg. ore
24 Kg. charcoal (90 per cent C)
12 Kg. limestone

the quantities required will be

1,640 Kg. ore
394 Kg. charcoal
197 Kg. limestone.

Assuming that the ore contains about 5 per cent of water to be driven off and that there is a loss of 5 per cent of material during crushing and handling, the following quantities will be required :—

1,640 plus 10 per cent = 1,804 Kg. crude ore
394 „ 5 per cent = 414 Kg. charcoal
197 „ 5 per cent = 207 Kg. limestone.

For No. (3)—

100 Kg. of dehydrated ore contain 60 Kg. of Fe and allowing 7 per cent loss in slag, the yield will be 55·8 Kg. of steel.

For 1 ton of steel $\frac{100}{55 \cdot 8} \times 1000 = 1{,}792$ Kg. of ore will be required.

Taking the bricquettes at

100 Kg. dehydrated ore
23 Kg. charcoal
20 Kg. limestone

the quantities for 1 ton of steel will be

1,792 Kg. ore
412 Kg. charcoal
358 Kg. limestone.

Assuming 10 per cent of water driven off from the ore and 5 per cent loss of material in crushing and handling, the materials required will be—

1,792 plus 15 per cent = 2,061 Kg. crude ore
412 „ 5 per cent = 433 Kg. charcoal
358 „ 5 per cent = 376 Kg. limestone.

Using these quantities we get the following estimates :—

(1) 65 per cent ore; output—10,000 tons steel.

		Shillings.
1,804 Kg. crude ore at 2 shillings per ton	...	3·608
414 Kg. charcoal at 25 shillings per ton	...	10·35
207 Kg. limestone at 10 shillings per ton	...	2·07

(continued)

	Shillings.
Crushing and dehydrating 1,804 Kg. ore at 2 shillings per ton	3·608
Crushing charcoal and limestone, 621 Kg. at 1 shilling per ton	0·621
Bricquetting 2,231 Kg. of mixture at 2·5 shillings per ton	5·578
Electrical energy, 2,500 K. W. hours at 0·01 shilling per K. W. hour ...	25·00
Lining of furnace	20·00
Electrodes	8·00
Labour at furnaces	6·00
General expenses	5·00
Management and supervision	5·00
Interest and depreciation on smelting plant and accessories at 10 per cent...	10·00
Cost of steel per ton ...	104·835

(2) 65 per cent ore; output—100,000 tons steel.

	Shillings.
1,804 Kg. crude ore at 1·5 shillings per ton ...	2·708
414 Kg. charcoal at 20 shillings per ton ...	8·28
207 Kg. limestone at 10 shillings per ton ...	2·07
Crushing and dehydrating ore, 1,804 Kg. at 1·5 shillings per ton... ...	2·708
Crushing charcoal and limestone, 621 Kg. at 1 shilling per ton	0·621
Bricquetting 2,231 Kg. mixture at 2 shillings per ton	4·462
Electrical energy 2,500 K.W. hours at 0·01 shilling per K.W. hour ...	25·00
Lining of furnace	16·00
Electrodes	6·00
Labour	4·00

		Shillings.
General expenses	... ...	2·00
Management	... ...	1·00
Interest and depreciation	... ...	4·50
Cost of steel per ton	...	79·349

(3) 60 per cent ore; output—100,000 tons steel.

		Shillings.
2,061 Kg. crude ore at 1·5 shillings per ton	...	3·091
433 Kg. charcoal at 20 shillings per ton	...	8·66
376 Kg. limestone at 10 shillings per ton	...	3·76
Crushing and dehydrating ore, 2,061 Kg. at 1·5 shillings per ton ...	...	3·091
Crushing charcoal and limestone, 809 Kg. at 0·8 shilling per ton ...	...	0·647
Bricquetting 2,562 Kg. mixture at 2 shillings per ton ...	...	5·12
Electrical energy 2,500 K. W. hours at 0·01 shilling per K. W. hour	...	25·00
Lining of furnace	... ...	16·00
Electrodes	... ...	6·00
Labour	... ...	4·00
General expenses	... ...	2·00
Management	...	1·00
Interest and depreciation	... ...	4·50
Cost of steel per ton	...	82·869

The foregoing estimates do not include the important question of the treatment of the scrap from the finishing works, which may amount to from one-fourth to half of the finished output. This has got to be resmelted and will require additional plant, and as this will be combined with the larger ore-smelting plant, we may take the following figures for the cost of resmelting:—

Cost of resmelting scrap per ton.

		Shillings.
50 Kg. limestone at 10 shillings per ton	...	0·50
Ferro alloys and aluminium ...	...	6·00
Labour ...	...	3·00
Electrodes ...	...	2·00
Lining of furnace ...	...	5·00
Electrical energy, 800 K. W. hours at 0·01 shilling per ton ...	...	8·00
General expenses and supervision	...	1·00
Interest and depreciation ...	...	2·00
Loss during smelting ...	...	5·00
Total	...	32·50

Say 33 shillings per ton.

Assuming that the scrap is returned to the smelting works free of charge, the resmelting of the scrap will reduce the cost per ton of the steel sold to the finishing works, but will increase the smelting costs per ton of finished steel.

(1) Thus on a 10,000 ton finished output (from 65 per cent ore) and allowing scrap equal to half the output, the costs will be "per ton of finished output" $105 + \frac{33}{2} =$ *121·5 shillings* or "per ton sold to finishing works" $\frac{121 \cdot 5}{1 \cdot 5} =$ *81 shillings.*

(2) On a 100,000 ton output from 65 per cent ore, allowing scrap equal to one-fourth the output, the costs will be "per ton of finished output" $79 \cdot 5 + \frac{33}{4} =$ *87·75 shillings* or "per ton sold to finishing works" $\frac{87 \cdot 75}{1 \cdot 25} =$ *70·2 shillings.*

(3) On a 100,000 ton output from 60 per cent ore, allowing scrap equal to one-fourth the output, the costs will be "per ton of finished output" $83 + \frac{33}{4} =$ *91·25 shillings* or "per ton sold to finishing works" $\frac{91 \cdot 25}{1 \cdot 25} =$ *73 shillings.*

On the basis of these estimates and confining attention for the present to the 65 per cent ore, it would appear probable that the cost of steel in the various manufactured forms in which it would have to be placed in the market would be on the average about 122 shillings per ton for a small output of 10,000 tons a year and about 88 shillings per ton for a fairly large output of 100,000 tons a year. To these figures must be added the cost of treatment for the conversion of the steel to manufactured forms and the cost of transport of the finished articles to a market.

In the next section I give some figures as to the demand for iron and steel in India and the market values of the various classes.

VII. THE CHARACTER AND SALE OF PRODUCTS.

The following statements, taken from the Annual Report of the Director-General of Commercial Intelligence in India, give a very fair idea of the imports of various classes of iron and steel goods imported into India during the year ending the 31st of March 1908:—

IRON.

Class of material	Quantity tons (2,240 lbs.)	Value £	Value per ton. Shillings
Cutlery and Hardware—			
Share of Bengal	...	157,348	...
" Eastern Bengal and Assam ...	...	3,715	...
" Bombay	...	66,710	...
" Sind	...	26,650	...
" Madras	...	35,359	...
" Burma	...	50,902	...
Total ...	...	*340,684*	...
IRON—*Old, for re-manufacture*—			
Share of Bengal	99	298	60·17
" Bombay	185	490	53·05
" Sind	3	10	76·92
" Madras	678	1,884	51·87
" Burma	88	542	122·48
Total ...	*1,053*	*3,224*	*61·23*
IRON—*Cast (Pig)*—			
Share of Bengal	21,038	84,370	80·20
" Eastern Bengal and Assam ...	93	435	93·54
" Bombay	9,216	40,598	88·10

Class of maaterial	Quantity tons (2,240lbs.)	Value £	Value per ton. Shillings
Iron—*Cast (Pig)—contd.*			
Share of Sind	165	652	78·79
„ Madras	930	4,174	89·74
„ Burma	1,233	5,781	93·80
Total ...	*32,675*	*136,010*	*83·24*
Iron—*Wrought—Anchors, cables and kentledge*—			
Share of Bengal	712	12,887	361·79
„ Eastern Bengal and Assam ...	183	3,980	435·80
„ Bombay	103	1,727	330·96
„ Sind	...	...	...
„ Madras	1	13	325·00
„ Burma	120	2,448	406·64
Total ...	*1,119*	*21,055*	*376·28*
Iron—*Wrought—Angle, bolt and rod*—			
Share of Bengal	1,144	9,292	162·40
„ Eastern Bengal and Assam ...	20	152	145·85
„ Bombay	290	2,604	179·49
„ Sind	40	323	161·29
„ Madras	2,328	21,562	185·21
„ Burma	454	3,812	168·00
Total ...	*4,276*	*37,745*	*176·49*
Iron—*Bar*—			
Share of Bengal	9,909	87,658	176·92
„ Eastern Bengal and Assam ...	209	2,216	212·05
„ Bombay	1,984	17,492	176·37
„ Sind	147	1,573	214·08
„ Madras	21,034	161,330	153·39

Class of material	Quantity tons (2,240 lbs.)	Value £	Value per ton. Shillings
IRON—*Bar—contd.*			
Share of Burma	5,601	44,395	158·52
Total ...	*38,884*	*314,664*	*161·84*
IRON—*Beams, pillars, girders and bridge-work—*			
Share of Bengal	237	2,311	195·30
„ Eastern Bengal and Assam ...	113	1,512	267·37
„ Bombay	1,606	23,165	288·48
„ Sind	1,026	8,011	156·12
„ Madras	2,012	25,925	257·67
„ Burma	3,523	42,525	241·42
Total ...	*8,517*	*103,449*	*242·92*
IRON—*Bolts and nuts—*			
Share of Bengal	1,831	37,577	410·40
„ Eastern Bengal and Assam .	25	484	394·29
„ Bombay	1,871	34,529	369·09
„ Sind	225	4,478	398·22
„ Madras	250	5,844	468·08
„ Burma	391	6,942	354·90
Total ...	*4,593*	*89,854*	*391·30*
IRON—*Hoop—*			
Share of Bengal	1,790	18,562	207·39
„ Eastern Bengal and Assam ...	9	75	160·42
„ Bombay	1,068	9,250	173·24
„ Sind	16	126	160·00
„ Madras	321	2,971	185·25
„ Burma	408	4,448	218·27
Total ...	*3,612*	*35,432*	*196·22*

Class of material	Quantity tons (2,240 lbs.)	Value £	Value per ton. Shillings
IRON—*Nails, screws, rivets and washers*—			
Share of Bengal	5,067	90,477	357·13
,, Eastern Bengal and Assam ...	31	426	274·39
,, Bombay	3,613	49,250	272·65
,, Sind	997	13,448	269·80
,, Madras	1,822	27,291	299·54
,, Burma	4,013	51,062	254·45
Total ...	*15,543*	*231,954*	*298·46*
IRON—*Pipes and tubes*—			
Share of Bengal	9,277	118,674	256·39
,, Eastern Bengal and Assam ...	8	133	324·39
,, Bombay	10,903	123,167	225·93
,, Sind	1,340	14,803	220·95
,, Madras	2,307	28,961	251·10
,, Burma	4,636	76,749	331·10
Total ...	*28,471*	*362,414*	*254·59*
IRON—*Sheets and plates not galvanised or tinned*—			
Share of Bengal	267	3,188	239·02
,, Eastern Bengal and Assam ...	22	280	258·66
,, Bombay	556	4,419	159·07
,, Sind	3	29	168·11
,, Madras	2,460	21,401	174·00
,, Burma	351	3,397	193·61
Total ...	*3,659*	*32,714*	*178·87*
IRON—*Rice bowls*—			
Share of Bengal	5,895	77,336	262·36
,, Eastern Bengal and Assam ...	...	...	...

Class of material	Quantity tons (2,240 lbs.)	Value £	Value per ton. Shillings
IRON—*Rice bowls—contd.*			
Share of Bombay	19	309	328·72
„ Sind	0·25	3	240·00
„ Madras	125	1,720	274·76
„ Burma	293	3,608	246·19
Total ...	*6,332·25*	*82,976*	*262·05*
IRON—*Wire*—			
Share of Bengal	2,010	29,010	288·71
„ Eastern Bengal and Assam ...	43	670	309·46
„ Bombay	1,899	26,407	280·62
„ Sind	341	4,394	257·97
„ Madras	370	5,173	279·69
„ Burma	419	6,094	291·02
Total ...	*5,082*	*71,748*	*282·22*
IRON—*Other manufactures of iron, or of iron mixed with steel.*			
Share of Bengal	7,053	116,668	330·83
„ Eastern Bengal and Assam ...	210	2,367	225·48
„ Bombay	467	12,893	551·92
„ Sind	1,502	13,756	183·21
„ Madras	105	1,820	345·35
„ Burma	1,237	22,789	368·52
Total ...	*10,574*	*170,293*	*322·09*
STEEL—*Angle, channel and spring*—			
Share of Bengal	14,236	108,754	152·78
„ Eastern Bengal and Assam ...	10	87	183·15
„ Bombay	6,226	46,386	149·01

Class of material	Quantity tons (2,240 lbs.)	Value £	Value per ton. Shillings
STEEL—*Angle, channel and spring—contd.*			
Share of Sind	1,432	10,450	145·93
„ Madras	1,570	13,330	169·79
„ Burma	784	7,241	184·68
Total ...	*24,258*	*186,248*	*153·55*
STEEL—*Bars*—			
Share of Bengal	35,205	265,368	150·75
„ Eastern Bengal and Assam ...	38	255	135·45
„ Bombay	44,433	320,605	144·31
„ Sind	14,891	106,760	143·39
„ Madras	3,682	32,617	177·16
„ Burma	898	8,476	183·24
Total ...	*99,147*	*734,081*	*148·08*
STEEL—*Beams, pillars, girders and bridge work*—			
Share of Bengal	27,006	192,680	142·69
„ Eastern Bengal and Assam ...	1,357	17,719	261·11
„ Bombay	12,784	96,217	111·41
„ Sind	8,302	62,852	151·41
„ Madras	1,323	11,544	174·49
„ Burma	1,899	19,115	201·77
Total ...	*52,671*	*400,127*	*151·93*
STEEL—*Cast*—			
Share of Bengal	1,183	27,380	462·71
„ Eastern Bengal and Assam ...	...	...	...
„ Bombay	2,552	34,402	269·56
„ Sind	118	1,397	236·57
„ Madras	337	8,270	491·09

Class of material	Quantity tons (2,240 lbs.)	Value £	Value per ton. Shillings
STEEL—*Cast—contd.*			
Share of Burma	473	5,379	227·51
Total ...	*4,663*	*76,828*	*329·47*
STEEL—*Hoop—*			
Share of Bengal	5,619	52,210	185·82
„ Eastern Bengal and Assam ...	...	...	...
„ Bombay	10,964	104,555	190·72
„ Sind	1,644	15,026	182·82
„ Madras	1,677	17,248	205·60
„ Burma	334	3,937	235·92
Total ...	*20,238*	*192,976*	*190·69*
STEEL—*Plates and sheets—*			
Share of Bengal	36,673	381,243	207·91
„ Eastern Bengal and Assam ...	140	2,351	335·73
„ Bombay	19,290	214,339	222·22
„ Sind	13,398	136,822	204·24
„ Madras	2,532	23,824	188·13
„ Burma	5,551	74,479	268·32
Total ...	*77,584*	*833,058*	*214·74*
STEEL—*Other sorts—*			
Share of Bengal	22,980	218,729	190·34
„ Eastern Bengal and Assam ...	1,330	20,366	306·79
„ Bombay	6,036	73,418	243·25
„ Sind	658	7,944	241·31
„ Madras	604	19,921	659·41
„ Burma	31,164	426,113	273·46
Total ...	*62,772*	*766,491*	*244·20*
Total steel—			
Share of Bengal	142,902	1,246,363	174·43

Class of material	Quantity tons (2,240 lbs.)	Value £	Value per ton. Shillings
Total steel—contd.			
Share of Eastern Bengal and Assam ...	2,875	40,778	283·70
„ Bombay	102,285	889,922	174·00
„ Sind	40,443	341,251	168·75
„ Madras	11,726	126,753	216·18
„ Burma	41,103	544,742	265·06
Total ...	*341,334*	*3,189,809*	*186·90*
RAILWAY PLANT AND ROLLING STOCK—*Carriages and trucks and parts thereof—*			
Share of Bengal	...	1,098,695	...
„ Eastern Bengal and Assam ...	...	42,632	...
„ Bombay	...	681,839	..
„ Sind	...	13,794	...
„ Madras	...	135,550	...
„ Burma	...	125,641	...
Total ...	...	*2,098,151*	...
Locomotive engines and tenders and parts thereof—			
Share of Bengal	...	509,855	...
„ Eastern Bengal and Assam ...	...	...	...
„ Bombay	...	347,341	...
„ Sind	...	17,583	...
„ Madras	...	188,374	...
„ Burma	...	103,024	...
Total ...	...	*1,166,177*	...
Materials for construction. Rails and fish plates of steel and iron—			
Share of Bengal	29,124	203,380	139·66

Class of material	Quantity tons (2,240 lbs.)	Value £	Value per ton. Shillings
Materials for construction. Rails and fish plates of steel and iron—contd.			
Share of Eastern Bengal and Assam ...	826	60,346	146'09
,, Bombay	21,048	188,112	178'74
,, Sind	3,783	29,070	153'66
,, Madras	10,023	79,338	158'30
,, Burma	3,152	20,811	132'04
Total ...	*67,956*	*581,057*	*171'01*
Sleepers and keys of steel and iron—			
Share of Bengal	2	267	2,272'34
,, Eastern Bengal and Assam ...	...	...	...
,, Bombay	18,171	125,924	138'59
,, Sind	0'05	1	400'00
,, Madras	14,471	103,821	143'49
,, Burma	...	...	...
Total ...	*32,644'05*	*230,013*	*140'92*

I do not propose to discuss these figures in any detail and they are inserted for the information of those who may have the necessary acquaintance with the costs of manufacture of the various classes of material mentioned, to be able to judge whether with steel, for which the smelting costs amount to from 88 to 122 shillings per ton, it would be possible to produce the finished articles at a cost sufficiently below the sale prices to leave a reasonable profit. The costs of manufacture are so varied and intricate that it would not be worth while for an outsider to attempt to discuss them in detail.

A few points may, however, be noted:—

The nearest markets to works situated at the Bababudan Hills are Madras and Bombay and the places which those ports supply. The freight to Madras would add about 15 shillings per ton to costs and that to Bombay about 30 shillings per ton, though it is quite possible that more favourable rates could be obtained.

In the case of railway materials supplied to the Madras and Southern Mahratta Railway, it is probable that the freight might be omitted from the calculation altogether, as the works would be situated on, or closely connected with, this railway system.

It is quite evident that the great bulk of the material imported into India could not be profitably supplied from works having a small output. The prices quoted for most of this material run from 140 to 200 shillings per ton and the difference between these figures and the cost of the steel at 122 shillings per ton would leave no margin for profit, even if it covered the costs of manufacture and transport. There are, however, some lines which I think might be supplied by a small concern, for instance:—

Steel castings.—These according to the statement average about 330 shillings per ton. In addition to the quantities there specified, there must be large imports of steel castings for railway purposes.

Steel forgings.—It is probable that in India these would be worth at least £10 per ton.

Tool and other special steels.—The demand for these is not very large, but they would probably afford a profitable line of work.

Railway tyres.—These are fairly expensive and will probably be worth about £14 per ton in India.

All of these lines can be manufactured without the necessity for a very large plant for which a very large and constant output is a *sine qua non*, and considering the fact that fairly useful labour can be obtained in India at

a cheap rate, it seems quite probable that they could be supplied in successful competition with imported goods.

For the cheaper varieties of steel the outlook is less favourable, but by no means without hope, the essential need being a steady market for a large output. It is obvious that the higher priced steels already mentioned would be very much more profitable in the case of a concern having a large output of other classes of steel owing to the lowering of general charges, and this would materially help to make the manufacture of the lower priced steel possible. To take the case of steel rails, these are quoted as having a value of 150 to 170 shillings per ton in India. If the steel can be made at 88 shillings per ton and if reheating and rolling costs 30 shillings per ton, there remains a balance of 30 shillings to 50 shillings per ton to cover transport and profit; and if the rails can be delivered on the railway, the transport charges would be practically wiped out. On these figures it looks as though the manufacture and supply of steel rails is not without hope of being profitable and the same would be true of certain classes of rolled sections.

CONCLUDING REMARKS.

The foregoing notes deal with some of the factors connected with the possible smelting of iron ores in Mysore in electrical furnaces. The information about the supply and cost of materials and of electrical energy is independent of the particular process or kind of furnace which might eventually be adopted and will, I hope, prove of some general utility. In the various estimates which I have put forward the only factors which may possibly be considered as having been underestimated are those relating to the cost of electrical energy and the amount of energy necessary to smelt a ton of steel. The estimate of 2,500 K. W. hours per ton of steel is, I admit, low, so

far as our present experimental knowledge goes, but I am still inclined to adhere to the opinion that this result is obtainable. At first it would almost certainly be exceeded and 3,000 K. W. hours would perhaps be a better figure for a small plant. This would increase the cost of energy by one-fifth and if at the same time the price per unit were increased from £3 to £3-10*s* per h.p. year, a further one-sixth would be added. The cost of energy per ton of steel would then be increased from 25 to 35 shillings, thus adding 10 shillings per ton to the cost of the steel. Even with such an addition I am of opinion that the higher-priced steels could be made at a profit and that there would still be a reasonable hope for making some of the lower-priced steels, provided a sufficiently large output could be maintained.

On the question of smelting I have confined my remarks to the Stassano Process and I am of opinion that a process of this description has great possibilities and deserves serious experimental development. There are many other furnaces now being used or tried and I hope to refer to some of them in a separate note. Those actually in commercial use are essentially of the nature of melting and refining furnaces and are not working on the reduction of iron ore. A number of furnaces are, however, engaged in the reduction of iron ore to pig iron on a more or less experimental scale and the results of the trials now being made will be watched with interest. So far as I am aware, no serious efforts have been made to determine the cost of converting pig-iron to steel in an electric furnace and this is a most important part of the combined process upon which some information is required. I have not dealt with the question of the production of steel from scrap, but the cost of this may be gathered from the data given. The cost depends largely on the price of scrap of good quality and I am unable to find that there is any large supply available at a reasonably low price. No doubt there is a good deal of steel scrap in India, but

most of this appears to find a ready market and if large quantities were required the price would probably not be below 50 to 60 shillings per ton. At such prices the production of steel from scrap would, I believe, be more expensive than production from the rich and cheap ores of Mysore.

There can be no question that the supply of ore in the Bababudan Hills is amply large for any demands which may be made upon it and that while the quality is very good indeed the cost of winning will be remarkably low. The character of the ore also appears to be very fairly uniform and this would be enhanced by proper sampling combined with the crushing and bricquetting which is necessary for the Stassano Process. It would seem therefore that under such conditions, if anywhere, a direct process, such as that of Stassano, should have a chance of success, even if it be considered that it would not be wholly satisfactory for dealing with the varied classes of ore obtainable in other places.

Whether a direct process for the manufacture of steel from ore, or an indirect process for the production of pig-iron and its conversion to steel may eventually prove to be the most suitable, I am of opinion that a very good case has been made out for some serious experimental work in Mysore with a very promising chance of being able to establish a medium-sized smelting work on a profitable basis for the production of the higher-priced steel goods and with a very fair possibility of being able to extend this into a larger concern capable of supplying some of the commoner forms of merchant steel.

MAP OF THE BABABUDAN IRON ORE AREA.

(IN POCKET.)

NOTE ON MAP.

ıe enclosed map shows the general distribution of ıron Ores of the Bababudan Hills referred to in these s (*vide* Part II, I, pages 58-67). The map is on a of 2 miles to an inch and has been compiled largely the work of Messrs. H. K. Slater and P. Sampath gar, Assistant Geologists,—the former of whom surd the northern portion of the area and the latter the ıern portion. Detailed reports on the geology of area will be found in Volume IX, Part II, of the ırds of the Mysore Geological Department.

GENERAL SERIES—BULLETIN No. 6

DEPARTMENT OF MINES & GEOLOGY

MYSORE STATE

OUTLINE

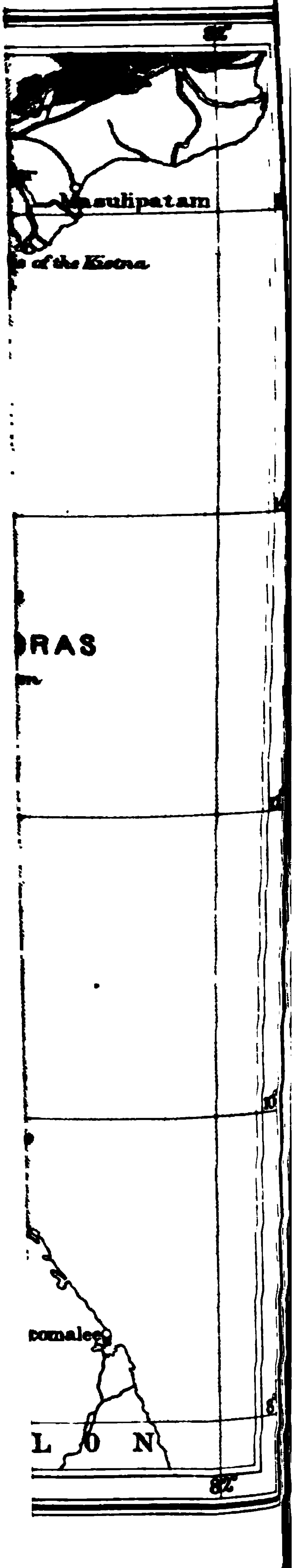
OF THE

GEOLOGICAL HISTORY OF MYSORE

BY

W. F. SMEETH, D.Sc., A.R.S.M.,
Director, Department of Mines and Geology

BANGALORE:
PRINTED AT THE GOVERNMENT PRESS
1915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OUTLINE OF THE GEOLOGICAL HISTORY OF MYSORE.

BY W. F. SMEETH, D.Sc., A.R.S.M.,
Director, Department of Mines and Geology.

THE geological formation of Mysore is confined, almost entirely, to the most ancient epoch in the history of the earth's crust of which we have any visible and tangible record. This epoch, which is known as the Archæan Period, was long anterior to all the great sedimentary formations in which fossil records of the gradual evolution of plant and animal life have been preserved and which are so extensively developed in Northern India and in other parts of the world.

The tabular statement on page 3 shows the order of succession and relative ages of the formations composing the earth's crust amongst which the limited range of the rocks composing the Mysore plateau may be noted.

The thickness shown for each formation is the maximum thickness of the sediments so far as known at present and the figures given here have been taken from the Presidential Address to the Geological Society of London, in 1909, by Prof. W. J. Sollas, LL.D., D.Sc., F.R.S. The age or duration of the various periods is based on the assumption that the sedements have accumulated at the rate of 1 foot in a century, and although no great accuracy can be claimed for these estimates, they may be useful as affording some idea of the lapse of time covered by the Geological Record.

NOTE.—Much of the evidence on which this account of the geology of Mysore is based has appeared from time to time in the Records of the Mysore Geological Department. A geological map of the State, on a scale of 8 miles to an inch is under preparation and is expected to issue towards the end of 1915.

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TABLE OF FORMATIONS.

Formations	Thickness Feet	Total years	Remarks
Cainozoic.			
Recent and Pleistocene ...	4,000		Man.
Pliocene	13,000		
Miocene	14,000		
Oligocene	12,000		
Eocene	20,000		Horses and larger mammals generally
Total ...	63,800	6,380,000	
Mesozoic.			
Upper Cretaceous ...	24,000		
Lower do	20,000		
Jurassic	8,000		Gigantic Reptiles.
Trias	17,000		Birds and small mammals.
Total ...	69,000	13,280,000	
Palæozoic.			
Permian	12,000		Indian coal-measures. Reptiles.
Carboniferous	29,000		
Devonian	22,000		Land Plants.
Silurian	15,000		Fresh water and terrestrial invertebrates.
Ordovician	17,000		Fishes.
Cambrian	26,000		Marine invertebrates, (many highly specialized).
Total ...	121,000	25,380,000	
Pre-cambrian			
Keweenawan	50,000(?)		
Animikean	14,000		Organic remains doubtful.
Huronian	18,000		
Total ...	82,000	33,580,000	
(Archæan Complex.)			
Laurentian (intrusive) ...			Geology of Mysore practically confined to this period.
Keewatin, etc.	?		

POST ARCHÆAN GEOLOGY OF SOUTHERN INDIA.

The story of these rocks is fairly well known and has been very lucidly summarized by Sir Thomas Holland in the delightful chapter on the Geology of India in Vol. I of the Imperial Gazetteer. At the close of the Archæan period Southern India formed part of an extensive land area composed of highly crushed and folded Archæan rocks. An extremely long period of denudation followed during which these rocks were slowly worn down, the upper covering of Dharwar schists being completely removed in places and the underlying gneisses and granites exposed. In places the sea encroached and permitted the accumulation of a great series of sediments which was subsequently raised to form land and somewhat crumpled in the process. The remains of these sediments, composed largely of shales, sandstones and limestones, now form a patch about 14,000 square miles in area, in

is no trace in Southern India which appears to have formed an exceedingly stable buttress of the earth's crust, while other portions of the crust were continually in a state of flux, being alternately depressed below the sea and raised again into dry land many times.

Towards the close of the Carboniferous period, there is evidence derived from the distribution of land fauna and flora that Southern India formed part of a great continental area extending to Africa and on to South America on the one side and on the other side possibly to Australia. This old continent, which has been called Gondwanaland, formed a barrier between a southern ocean and a great central Eurasian sea extending from Asia across Northern India, where the Himalayas now stand, into Europe and of which the Mediterranean is a small relic.

Towards the close of the Carboniferous period the geological record is again taken up in Southern India. Denudation had been slowly wearing down the old Archæan and Pre-cambrian rocks and the larger rivers had gradually worn their valleys down to near their base level of erosion with gradual widening of the valleys and the development of slowly moving rivers and large swampy areas. In these areas large tracts of fresh-water sediments were formed which included the debris of the luxurious vegetation of the coal measures. The result was the accumulation of a considerable thickness of sediments, known as the Gondwana formation—from Permo-carboniferous to Jurassic times—of which various small patches have been preserved along the eastern side of the Peninsula. The lower portion of this formation constitutes the coal measures of India, and in the south the most important patches are those of the Godaveri valley which include the Singareni coal field.

At the close of the Gondwana epoch, slight alterations in level permitted encroachments of the sea of which

records are preserved in small, but extremely interesting, deposits at Trichinopoly, Cuddalore and Pondicherry containing marine fossils of Cretaceous age. After this the record is scanty and uneventful and comprises a few beds of presumed Tertiary age in Travancore, the Cuddalore Sandstones of the East Coast from Vizagapatàm to Tinnevelly—of Pleistocene age—and the various recent blown sands, alluvium and soils of the coastal strips.

As a contrast to this peaceful story, it may be noted that towards the end of the Cretaceous period the old Gondwana continent began to break up and the land connection between Southern India and Africa disappeared under the sea. In the North of India a great series of movements began about the same time, extending into the Tertiary period, which resulted in the gradual rise of the Himalaya and the driving back of the central sea towards its present Mediterranean limits. These movements were accompanied by igneous action on a gigantic scale of which the most striking memento is to be found in the lava flows forming the Deccan Trap, the remains of which form a horizontal layer covering an area of 200,000 square miles in Bombay, Central India and Hyderabad.

In Southern India, therefore, if we exclude the coastal strips we have an area which is formed almost entirely of the most ancient series of rocks of which any visible record exists, and this appears to have remained uncovered by any more recent formation—and almost without movement—during the whole of the vast period represented by the fossiliferous formations of other parts of the crust of the earth.

With this very brief glance at the post-Archæan geology of Southern India we may now turn back to consider the nature of the immensely old Archæan complex as exhibited in Mysore—which comprises an area of about 29,000 square miles—and in doing so we shall en-

deavour to take the components in the order of their formation, starting with the oldest.

THE DHARWAR SYSTEM.

The oldest rocks recognized in Mysore are the Dharwar schists which appear to possess a close resemblance to the Keewatin formation of North America. In other parts of India certain gneisses and schists—such as the Bengal gneiss and the Khondalites of Vizianagram—are considered to be older than the great mass of the Peninsular Gneiss and possibly of pre-Dharwar age. Clear evidence on the latter point is however lacking, and in Mysore no rocks older than the Dharwars have been recognized.

The schists. The Dharwar schists are largely composed of lava flows, associated igneous intrusions and their crushed representatives. The base of the system is not visible as it has been removed by the intrusion of the underlying granites and gneisses. On lithological grounds the system can be divided into a *lower* and an *upper* division without any perceptible break or unconformity between them. The lower division is composed essentially of dark hornblendic rocks—such as hornblende schist and epidiorite—which are probably metamorphosed basalts and diabases in the form of lava-flows, sills, etc., and very possibly some pyroclastic accumulations. The upper division is more varied and consists largely of rocks characterised by the presence of chlorite—such as greenstones and chlorite schists and less commonly mica-chlorite schists and mica schists. Many of the greenstones still exhibit igneous characters and appear to pass insensibly into chlorite schists. In places the micaceous members also appear to grade into rocks of recognizably igneous character.

Taken as a whole the Dharwar rocks afford evidence of very extensive igneous action and many of the more

schistose forms can be regarded as highly crushed and altered igneous rocks. Whether amongst the more schistose members there are rocks of sedimentary origin remains doubtful, as clear evidence is wanting, but it does not seem impossible that all of these rocks may have been derived from igneous material by metamorphic action.

Apart from the undoubtedly igneous types and these doubtful schistose types, the system contains a number of other types, the physical and chemical characters of which cause them to stand out more prominently than their actual abundance would otherwise warrant. These are conglomerates, banded-ferruginous quartzites, quartzites and limestones, all of which would usually be regarded as indicative of sedimentary action, and if such action were admitted in the case of these associated types it would go far towards easing the way for accepting a sedimentary origin for many of the more obscure highly schistose rocks associated with them.

Conglomerates.

The more closely the conglomerates of Mysore are studied the less probable does their sedimentary origin appear to become. In many cases there is satisfactory evidence that they are crush-conglomerates formed in shear zones in the schists or in one of the subsequent gneisses or in both. Other cases which have not been closely studied may still be open to question but, on the whole, evidence favours the view that their origin is autoclastic and not sedimentary.

Banded ferruginous quartzites.

The problem of the banded ferruginous quartzites presents much greater difficulty owing largely to the fact that their contacts with other rocks are very obscure. Owing to their weather-resisting qualities the adjoining rocks are generally weathered and generally also obscured by a talus of quartzite blocks. Contacts are therefore seldom observed, and when found are usually non-commital.

These rocks occur in extensive beds or bands in both the lower and upper division of the Dharwars—being rather more extensively developed in the latter. Frequently folded at steep angles there is little doubt that they were once practically horizontal. On part of the Bababudan hills there is a capping of these rocks which is comparatively horizontal, with moderate undulations, and which is still from 200 to 300 feet in thickness. They are composed mainly of alternating bands of finely granular quartz—sometimes extremely fine—and magnetite. Hæmatite is usually present and often increases, to the practical exclusion of magnetite, towards the weathered surfaces. This widely distributed series does not appear to be associated with coarser clastic or sedimentary material such as might be expected to occur if it was formed of ordinary sediments with a tendency to become coarse in the neighbourhood of shore lines. On the other hand, bands of it are found to alternate sharply with undoubtedly igneous material in the shape of basic flows and sills. On account of these difficulties some American geologists consider that the corresponding rocks in the Lake Superior region were formed in tranquil water, mainly as chemical precipitates, and that the associated lava flows were sub-aqueous flows. This interesting and ingenious hypothesis would tend to render a considerable proportion of the Dharwar flows sub-aqueous owing to the numerous layers of the banded ferruginous rocks and to the absence of conglomerates and coarse sedimentary material in the intervening zones, such as might be expected to be formed during a change from sub-aqueous to sub-aerial conditions. On the other hand, if the series is not of sedimentary or chemical origin, it is extremely difficult to find a satisfactory explanation for it on account of the completeness of the metamorphism and the difficulty of finding good contacts. It is not impossible that these banded rocks represent sills of highly ferrugi-

nous character subsequently altered to quartz and magnetite or even, in some cases, sills of a quartz-magnetite rock such as will be referred to later in connection with the Charnockite series. Whatever the origin of these rocks, there can be little doubt that their banded character is largely secondary. As to their sedimentary or aqueous character, definite proof is lacking, but the great concensus of opinion is in favour of such a view.

Quartzites.

We may now pass to the quartzites, some of which are practically all quartz, while some are felspathic and some micaceous. There is considerable doubt to what extent these can be regarded as the metamorphosed representatives of sedimentary sandstones. There is a great variety of types and they appear to be of different ages. Many of the beds originally mapped as quartzite have proved on close examination to be altered and silicified quartz-porphyries some of which retain enough of the prophyritic character to be recognizable. Others, entirely quartzose, are occasionally found to exhibit intrusive contacts with adjoining rocks, while others of a later date penetrate the subsequent granitic gneiss and even pass from the gneiss into the schists.

There can be little doubt that many of these quartzites are crushed and recrystallized quartz-veins and quartz-porphyries, and possibly felsites, and it is at least open to question whether we have any which are genuine sedimentary rocks.

Limestones.

Finally there are a number of beds or bands of limestone or dolomite which ordinarily would be regarded as of aqueous origin. They are most numerous in the upper, chloritic division, and it may be noted that a large number of the greenstone and chlorite-schist beds are characterised by an abundant development of calcite, dolomite, or ferro-dolomite not only in the doubtful

schistose members, but also in those which are distinctly igneous. In addition, some of the gneissic granite bands associated with the schists develop calcite which in places becomes extremely abundant. By development of calcite, chiefly at the expense of the felspars, we get a series of rocks which approach limestone, and near by we have limestone bands sometimes very siliceous or chloritic and sometimes comparatively pure. The association is suggestive, though it is not clear that a continuous series has been detected, and possibly the purer limestone bands have been concentrated along fissures or zones of weakness. The proof that these beds have been so formed is naturally difficult, but there is much to suggest it.

To sum up--we have in the Dharwar System in Mysore a great series of lava-flows, sills, etc., and their crushed schistose representatives; associated with these are various doubtful schists which are more usually regarded as sedimentary, but which may possibly be igneous. There are also a number of subordinate bands or layers of more distinctly sedimentary habit, such as conglomerates, banded ironstones, quartzites and limestones which are almost universally regarded as of sedimentary origin, but which are regarded in Mysore as probably formed from igneous material by metamorphic and metasomatic changes. In some cases there is strong evidence for this, but conclusive proofs are difficult to find, and many more instances will be required before such a proposition can be stated in general terms.

Ultrabasic Intrusives.

Passing now from these components of the Dharwar System, we come next to a series of rocks which may be classed as ultra-basic. These consist of amphibolites—often in the form of actinolite or tremolite schists—amphibole-peridotites, peridotites and dunites with their alteration products potstone, serpentine and magnesite. They appear to be sills, dykes and intrusive bosses in the mass of the

schists and are regarded as belonging to the Dharwar System on account of the evidence of their having been cut off and broken up by the subsequent intrusive gneiss. They are of importance for their mineral contents and contain considerable deposits of iron-ore, chrome-ore and magnesite. It is very probable that the Chalk Hills of Salem, which are conspicuous on account of the abundance of veins of white magnesite, belong also to this series.

Other intrusives.

Finally, we have some large intrusive masses of diabasic or dioritic character which appear to be later than many of the rocks already mentioned, but prior to the gneiss and so regarded as of Dharwar age.

At the close of the Dharwar age, the whole of Southern India was covered with a mantle of these Dharwar rocks several thousand feet in thickness, but successive intrusions of granite from below gradually penetrated or ate into the over-lying mantle and this, combined with folding and faulting, caused the lower surface of the mantle in contact with the granites to become a very uneven one. Subsequent denudation for many millions of years removed the greater portion of the mantle of Dharwars, with the result that we now see the underlying granite and granitic gneisses exposed at the surface. The comparatively narrow strips of the Dharwar schists which still remain are but the deeper fragments of the once thick, continuous layer.

Distribution of the schists.

The total area of the Dharwar schists in Mysore is nearly 5,000 sq. miles representing approximately one-sixth of the area of the whole State and is distributed mainly as follows :—

(1) *Kolar Schist Belt.*—Situated near the eastern side of the State in the Kolar District. It extends north and south for about 40 miles, with a maximum width of 4 miles, the total area being about 100 sq. miles.

It is composed entirely of the dark hornblendic rocks of the *lower* division of the Dharwar schists with some banded ferruginous quartzites close to its eastern and western edges and some bands of amphibolite some of which are intrusive.

The Kolar Gold Field is contained within a length of 5 miles towards the southern end, and the workings are now approaching a vertical depth of 1 mile below surface.

Indications of gold have been found further north at various points, but successful working has not yet been established.

(2) *Chitaldrug Schist Belt.*—This runs through the middle of the State with a N.N.W trend in the Chitaldrug District, where it has a maximum width of 25 miles, and passes southwards through the Tumkur and Mysore Districts in which it becomes split up into narrow bands finally disappearing a few miles south of Seringapatam. The belt extends north of the State into the Bombay Presidency, the total length in Mysore being about 170 miles and the area nearly 2,000 sq. miles.

The main portion of the Belt is composed of chloritic schists of the *upper* division, but at the sides and in some of the narrower bands in the Mysore District there are considerable masses of the dark hornblendic schists. Numerous bands of ferruginous quartzite occur throughout the belt and quartzites are abundant in places. Towards the western side, in the Chitaldrug and Tumkur Districts, are numerous bands of limestone—chiefly magnesian—and numerous bands and patches of iron and manganese ores. The iron ores are mostly soft hæmatites and limonites and the manganese ores are mostly highly ferruginous.

(3) Sundry small bands and patches of the older hornblendic schists occur in the Hassan District and are noticeable chiefly for the number of sills, dykes or intrusive masses of amphibolite and peridotite with which are associated iron and chrome ores and magnesite. The better classes of chrome ore and magnesite occur further south in small patches of peridotite and dunite in the Mysore District.

(4) *Shimoga Schist Belt.*—This occupies a large part of the Kadur and Shimoga Districts and extends northwards through the Dharwar District of the Bombay Presidency. In Mysore it is broken up into a number of large irregular patches separated by the later granites and gneisses, the total schist area being between 2,500 and 3,000 square miles. The dark hornblendic schists occur chiefly along the Western ghats and around the Bababudan hills while the areas around Ubrani, Koppa, Kumsi and Shikarpur consist very largely of chlorite schists and greenstones with some mica schists.

Quartzites of various kinds are abundant and very noticeable, and numerous bands of magnesian limestone occur in the Ubrani, Channagiri and Kumsi schists. Banded ferruginous quartzites are abundant and large quantities of hæmatite and limonite occur along the eastern hills of the Bababudan chain. Gold is widely distributed but the lenses or veins of ore, though often rich, are small and lack continuity, and successful mining has not been established.

Manganese ores are widely distributed in the chloritic schists but many of the deposits are small. Some of the deposits, however, are of considerable extent and

some 300,000 tons of ore have been mined and exported already. The ore is of fairly high quality and there are also very large quantities of more highly ferruginous ores which cannot be exported or utilized at present.

(5) In addition to the above, small shreds, patches and fragments of the various schists—chiefly those of the lower hornblendic division—are widely scattered throughout the later intrusive gneisses and granites.

GRANITES AND GNEISSES.

With this brief notice of the Dharwar System, we may pass on to the subsequent granites and gneisses which now occupy by far the greater part of the whole area.

Champion gneiss.

The earliest of these is a comparatively fine grained micaceous gneiss with bands and veins of coarser granite, pegmatite and quartz. It is usually highly crushed and frequently contains zones of conglomerate composed not only of round to sub-angular fragments of the various granitic materials but also patches and lumps of the adjacent Dharwar rocks including the banded ferruginous quartzites. This gneiss was first recognized as a wide band near the eastern edge of the Kolar hornblendic schists into which it intrudes in tongues. Some distance south of the Mysore mine, the gneiss extends across the strike of the schists and then continues southwards near the western edge of the schist belt. From south of the Mysore mines it sends some tongues northwards into the schists which are soon lost on surface, but some of them have been recognized in the deeper workings of the Mysore mine a mile or so to the north of the outcrops. The gneiss is often characterized by the presence of grains or blebs of opalescent quartz, the colour varying from a slight bluish milkiness to brown or dark grey, and has

been referred to as *opalescent-quartz gneiss.* As a less cumbersome name and on account of its intimate and probably genetic connection with the auriferous veins of the Champion *lode* of the Kolar Gold Field, it is proposed to call it, for the time being, the *Champion gneiss.* Other patches of what is believed to be the same gneiss have been recognised more recently in the Shimoga, Chitaldrug and Kadur Districts, and several of these contain or form friction-breccias or agglomerates which at one time were regarded as undoubtedly sedimentary conglomerates.

The Champion gneiss represents a very early period of granitic intrusion into the Dharwar schists. Many of the highly crushed quartz-porphyries or fine granite-porphyries which have been alluded to as occurring in bands among the Dharwar schists also contain similar opalescent quartz-blebs or phenocrysts and may very possibly be genetically connected with this early Champion gneiss.

The remnants of the latter are not very extensive, and there is evidence of their having been intruded and cut off by the next succeeding formation which is the great gneissic complex of Mysore and probably of Southern India as a whole.

Until recently this gneissic complex has usually been regarded as the oldest formation of Peninsular India and the term "fundamental," which has been freely applied to it, has usually carried with it the idea that it is the basement rock on which all the others—including the Dharwars—have been laid down. Detailed work over the greater portion of Mysore has shown that this is not the case and that this great gneissic complex is everywhere intrusive into the Dharwar schists and the Champion gneiss. It seems desirable, therefore, to avoid the use of the word "fundamental," and as the complex is probably the most extensive formation of Peninsular

India it is proposed to call it the "*Peninsular gneiss*." (1)

Peninsular Gneiss.

This Peninsular gneiss which underlies and intrudes the Dharwar System and the Champion gneiss is a complex of various granites, but so protean that no adequate description can be given here. It is the most extensive and widely distributed rock in the State and is used largely for building and structural purposes. The various granites, of which three are often distinctly recognizable, give evidence of successive intrusion and the fact that the earlier forms contain their own pegmatites, which are truncated by subsequent forms, points to a long continued period of plutonic activity. Frequently, the various members mingle either by repeated injection or absorption or crushing and shearing, and we get zones or areas which are highly banded or crushed or with complex flow structure. Other portions are more homogeneous and appear as granite masses. Amongst these latter are some which may be definitely later in age than the gneiss as a whole, but it is often difficult to decide one way or the other.

Evidence of the intrusion of the Peninsular gneiss into the Dharwar Schists is abundant and the former bristles, to a variable extent, with lenses, patches, and fragments of the Dharwars chiefly, as might be expected, belonging to the lower or hornblendic division.

It would take too long to enter into any account of the evidences of intrusion or of the contact metamorphism of the schists, and we may pass on to the next formation succeeding the Peninsular gneiss.

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(1) The suggestion that the term "*fundamental*" might be altered to something else was made to me by Dr. H. H. Hayden, C.I.E., Director of the Geological Survey of India, who pointed out that some people still regarded this great gneissic complex as the oldest basement rock of the Peninsula. It is not impossible that some particular gneiss may be shown to be older than the Dharwars, and in the event of such being found, the term "fundamental" might suitably be applied to it.

W. F. S.

Charnockite.

This next formation is itself highly complex, but, thanks to the genius of Sir Thomas Holland, it can be recorded and summarily dismissed with the name Charnockite.[1] It is a huge plutonic complex, characterized chiefly by the presence of hypersthene, in which the alternating bands, frequently steeply inclined, vary from an acid hypersthene-granite through various intermediate forms to hypersthene-norites and hypersthenites. These rocks form the great mass of the Nilgiris to the south of Mysore and come into Mysore on its eastern, southern and western borders where they are found distinctly penetrating the Peninsular gneiss both as tongues and

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the continuation of the chain northwards through the Tumkur and Chitaldrug Districts. Like most of the plutonics of Southern India it also is complex and is composed of a mixture of red and grey granites, sometimes coarse, sometimes porphyritic, and sometimes so intermingled or deformed as to become gneiss. It intrudes all the previously mentioned formations including the Charnockite. It is probable that other isolated masses in Mysore—for instance Chamundi Hill and the Arsikere and Banavar masses—may belong to the same age, and it is possible that the ornamental porphyry dykes of Seringapatam may be phases of this intrusion.

This completes the distinct members of the Archæan complex which have been definitely recognized in Mysore, —with the exception of various hornblendic and other basic dykes which need not be referred to here.

Dykes.

Subsequent to the formation and folding of the Archæan complex, the whole country has been traversed by a series of basic dykes—chiefly dolerites—which from their freshness and the absence of deformation are regarded as post-Archæan, and it has been suggested that they may be of Cuddappah (Animikean) age.

Laterite.

The only other rock formation in Mysore is laterite which is of comparatively recent (possibly Tertiary) formation and forms a horizontal capping on the upturned edges of the much denuded Archæans. There is little doubt that it is mainly an alteration product of the underlying rocks, but the subject is too complex and variable to permit of further reference to it here.

Tabular View of Mysore Rocks.

The foregoing sequence of events in the history of the rocks of the Mysore plateau may be exhibited in the following tabular statement:—

		1. Recent soils and gravels.	
Possibly Tertiary.		2. Laterite. Horizontal sheet capping Archæans.	
Pre-Cambrian (Animikean)		3. Basic Dykes. Chiefly various Dolerites.	
		Great Eparchæan Interval.	
Archæan.		4. Felsite and Porphyry dykes.	
		5. Closepet Granite and other massifs of corresponding age.	
		6. Charnockite, Norite and Pyroxenite dykes.	
		7. Charnockite massifs.	
		8. Various hornblendic and pyroxene granulite dykes.	
		9 Peninsular gneiss.	Granite and gneissic complex.
		10. Champion gneiss.	Granite porphyry, micaceous gneisses, felsites and quartz prophyries usually containing opalescent quartz and frequently associated with autoclastic conglomerates.
		Eruptive Unconformity.	
	Dharwar System (probably Keewatin).		Including also :—
		11. Upper (chloritic) division. (Greenstones and chlorite schists).	Amphibolites, peridotites, etc., mostly intrusive. Conglomerates (autoclastic). Banded-ferruginous-quartzites ; origin doubtful, possibly igneous. Quartzites and quartz-schists, mostly intrusive. Limestones : probably secondary. Mica schists ; metamorphic igneous. Intrusive masses of dioritic and diabasic character.
		12. Lower (hornblendic) division. (Epidiorites and hornblendic schists).	
		(Unknown).	

It will be seen that the main features of the geological history of the Mysore plateau belong to a very remote and hoary past—a past contemporaneous with the very earliest period of formation of the crust of the earth of which we have any geological record. Very possibly it was a period anterior to the dawn of life, though this is by no means certain. At any rate, it was long anterior to the formation of all those great sedimentary systems in which the geological records of the evolution of life from earlier to later forms have been preserved and which are found but sparingly represented along the coastal margins of Peninsular India.

All the central portion of Southern India revelled in a long orgy of igneous activity in the early dawn of geological history, as witnessed by the character of the Archæan complex which has been faintly indicated. Once this orgy was over and the great crushing and folding movements which accompanied it had ceased—possibly something like 40 or 50 million years ago—the country settled down to a prefectly steady and uneventful course of denudation—almost a lethargy from which it has not yet awakened.

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DEPARTMENT OF MINES & GEOLOGY

MYSORE STATE

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DEPARTMENT OF MINES & GEOLOGY

MYSORE STATE

MINERAL RESOURCES OF MYSORE

A BRIEF ACCOUNT OF THE MORE IMPORTANT ECONOMIC MINERALS, THEIR OCCURRENCE AND DISTRIBUTION WITH NOTES ON THEIR MINING AND METALLURGICAL TREATMENT AND USES.

BY

W. F. SMEETH, D.Sc., A.R.S.M.,

Director

AND

P. SAMPAT IYENGAR, M.A.,

Assistant Geologist

BANGALORE

PRINTED AT THE GOVERNMENT PRESS

1916

W D 1417—GPB—1,000—30-8-16

CONTENTS.

TABLES AND STATEMENTS.

Mineral Resources of Mysore.

Introductory.

THE following brief account of the more important economic minerals of Mysore has been compiled at the request of the Government of Mysore for a brief bulletin, giving an account of the occurrence and distribution of the minerals of the State, their geological relationship, mining and metallurgical treatment and possibilities of exploitation and use. It is intended that the bulletin shall be translated into Kanarese so that all classes of the community may have an opportunity of taking an interest in the minerals and their development. It has been a matter of considerable perplexity to decide what should be included and what omitted and every effort has been made to keep the bulletin as brief as possible, without omitting features of importance, and to avoid unnecessary technicalities.

A special map has been prepared and included in which the two main rock systems, *viz.*, the Dharwar Schists and the Granitic Gneisses are shown. The distribution of the various minerals is indicated by symbols at points where they have been worked recently or where old workings occur or where noticeable quantities have been discovered.

For those who wish to have further information about the formations a geological map, on a scale of 8 miles to an inch, has been prepared and will be issued separately showing the distribution and relationships of the principal rock types and formations as disclosed by the Geological Survey.

A brief bulletin (Bulletin No. 6) giving an outline of the geological history of the State is in the press and will issue

shortly. This may be referred to in explanation of the map or in connection with geological features alluded to in the present publication in connection with the occurrence and distribution of minerals.

With regard to metallurgical treatment it may be noted that the only metallurgical work in the State is the treatment of the gold ores of the Kolar Field with the exception, perhaps, of the now practically extinct local iron-smelting and steel-making industry. It is not possible, therefore, to give specific accounts, based on actual practice and results, of the treatment of other ores and minerals under local conditions. The problem of utilizing local ores and minerals and developing metallurgical industries is however a fascinating one and has been, from time to time, the subject of much discussion and attention and it has been thought desirable, for the information of the public, to give brief notes of processes, uses, etc., of such of the minerals as appear to provide near or remote possibilities of development under local conditions. Such notes, which include in some cases provisional estimates of costs, must be accepted with due caution and reserve. They are based on experience derived from other countries in which many of the conditions are different and although attempts have been made to allow for local factors so far as they are known or can be foreseen it must not be forgotten that commercial success depends on a multitude of adjustments some of which are of considerable delicacy.

It is hoped however that the notes given will be both interesting and useful and will help towards a clearer understanding and discussion of the problems involved.

The minerals dealt with vary greatly in quantity and commercial value and some are little more than specimens of scientific interest. They may be divided into groups as follows:—

I. *Metalliferous minerals.*—Ores of gold, silver, iron, manganese, chromium, copper, lead and antimony.

II. *Minerals used in various industries* :—

(*a*) ABRASIVE MATERIALS.—Corundum, garnet and mill-stones.

(*b*) REFRACTORY MATERIALS.—Mica, asbestos, pot-stone, magnesite, chrome-iron ore and fire clay.

(*c*) MINERAL PIGMENTS.—Red and yellow ochres.

(*d*) MATERIALS USED FOR AGRICULTURE, CHEMICAL INDUSTRIES AND FOOD.—Including lime, apatite, pyrites, earth-salt and earth-soda.

III. *Materials for construction, etc.*—Lime-kankar, limestone, brick and tile and pottery clays, kaolin, felspar, building and ornamental stones.

IV. *Rare minerals and minerals of limited occurrence.*—Including monazite, columbite, samarskite, beryl, and graphite.

I. Metalliferous Minerals.

Gold.

Gold is the most important mineral product of the Mysore State and in point of value the produce of the Mysore Gold Mines stands second amongst the minerals of the Indian Empire being surpassed only by coal the total value of which is now rather more than 1½ times the value of the gold from the Kolar Gold Field.

In 1914 the total value of the minerals of India for which returns are available amounted to about 15 crores of rupees (£10,000,000) out of which the gold from Mysore contributed Rs. 3,25,36,710 (£2,169,114) or nearly 22 per cent of the total value of Indian minerals. Since the commencement of modern mining operations in 1882 to the end of 1914 the total gold production of Mysore has been a little over Rs. 63½

crores (£42,466,790) the whole of which has come from the Kolar Gold Field with the exception of Rs. 43,170 obtained from trial crushings from a few outside mines. In a later section the yearly production is shown in tabular form and a diagram is given showing the yearly progress of the principal mines from the commencement of operations.

Old workings.—Gold mining is by no means a new industry in Mysore. Hundreds of old workings have been found and bear witness to a widely extended industry in ancient times. There is little historical or traditional information about these workings or the people who made them. Doubtless some are very ancient, while others are of no great antiquity and the rate of gold production must have been quite small. The total amount of gold obtained was no doubt considerable, but even this was in all probability but a fraction of the amount since obtained from the Kolar Mines and is unlikely to have exceeded a few million pounds sterling or a few crores of rupees.

The distribution of the principal old workings is shown on the accompanying map in which the symbol for gold represents in most cases an old working or a group of workings. It will be seen that the workings are confined to the belts and patches of the Dharwar Schists and that they are absent from the great mass of the later intrusive granites and gneisses. It would lengthen this bulletin too much to give a detailed list of these workings, but the more important will be referred to in connection with their geological occurrence and with brief accounts of the work done in investigating them.

General character.

Many old workings still remain as large open pits or as irregular adits, tunnels or burrows. Some have been more or less filled in by natural collapse or by the washing in of debris, soil, etc., and in many cases the filling has been so complete that little or no indications of old workings remain. On the Kolar Field some of these workings extend to a depth of 300 feet and at Hutti, in the Nizam's Dominions, they are said to reach a depth of some

640 feet. The majority are however much shallower and many are mere surface excavations. Dumps of broken rock and quartz are generally found close by and sometimes give a clue to the presence of the workings when the pits themselves have been completely filled in and covered with soil and vegetation.

Value of old workings as indicators.

Ancient workings for gold are no doubt a valuable indication of the presence of gold and of the existence, at one time, of small or large patches of valuable gold ore. It is possible that, as the richer patches were worked out or abandoned, workings were opened on comparatively poor ore which would not even pay under modern conditions; but on the whole it is probable that most workings were on comparatively rich ore. The enormous amount of modern work which has been done on these old workings has proved conclusively that in the majority of instances they do not indicate the existence of valuable deposits immediately beneath them. The mines on the Champion Lode at Kolar, the Hutti Mine in the Nizam's Dominion and one or two mines on the Anantapur Field are exceptions which prove the rule out of a large number of workings below which the absence of valuable deposits has been practically ascertained. The old workings on the Champion Lode at Kolar followed each other in close succession for four or five miles along a well-defined line and were excavated on a number of rich shoots in the quartz vein, or succession of veins, which carry the gold. The shoots are sufficiently large or sufficiently numerous to permit of new ones being searched for and opened up before the earlier found ones are exhausted and the fact that they are mostly distributed along a nearly continuous vein of quartz or lode matter facilitates and directs the search. The numerous old workings along a line at surface is an indication of these favourable conditions. Elsewhere in the Kolar Gold Field and in other parts of Mysore these conditions do not exist to anything like the same extent, but hundreds of old workings exist which are isolated or in irregular groups and

which indicate the former existence of small isolated lenses or shoots of rich ore, or rich pockets in low grade zones or superficial accumulations of the weathered, and possibly enriched, debris of low grade veins or lode matter. The sanguine hopes which have been entertained about these workings, many of which are of considerable size and depth, have not been realized notwithstanding the large amount of work and money expended. The amount of money expended on the prospecting of these old workings in Mysore—outside of the Kolar Gold Field—is in the neighbourhood of 30 to 40 lakhs of rupees and so far not a single paying mine has been discovered.

Quartz outcrops valueless.

Numerous quartz veins traverse the schists and many of them outcrop at surface. Some of these outcrops are close to old workings and in the early days of prospecting were regarded as valuable indications of gold. Since then a large number of these outcrops have been tested and in many places trenches and shafts have opened them up and have demonstrated their valueless character. Occasionally assays of a few dwts. have been obtained and in two instances in the neighbourhood of Kudrikonda small outcrops of quartz have been found recently from which assays of some ounces per ton were obtained. We may take it as an almost universal rule that outcropping veins are valueless. The systematic search for gold by the ancient workers as revealed by old workings has resulted in the almost complete removal of outcrops carrying valuable amounts of gold and in the majority of cases these shoots or pockets have been completely cleaned out. There is no doubt that other shoots, lenses and pockets occur at varying depths below surface and give no surface indications of their existence. Many of these have been opened up in the course of deep prospecting, but with the exception of those on the Kolar Field all have proved to be small and erratically distributed rendering the cost of prospecting and mining greater than the value of the gold recoverable.

These conditions render the work of the prospector

difficult and very expensive, and the results obtained so far are most discouraging and disappointing. There are a few points at which further work is expected to be carried on after the war and it is possible that some zones of low grade lode matter may be found of sufficient extent and under sufficiently favourable conditions for cheap treatment to permit of their being worked, but we cannot shut our eyes to the fact that the hopes based on the success of the Kolar Mines and on the existence of numerous old workings in other parts of the State have dwindled very seriously with the progress of survey work and deep prospecting.

A very brief account of the distribution of the gold in the various geological formations and of the results of modern prospecting work at the more important points will now be given. A brief account of the formations will be found in Bulletin No. 6 and they will not be described in any detail here. Further details of the work done will be found in the Reports of the Chief Inspector of Mines and in the Records of the Geological Department the summarized contents of which will be found at the end of this Bulletin.

The older known workings have been described by Bruce Foote in his "Auriferous Tracts in Mysore" (1887), extracts from which will be found in Rice's Gazetteer of Mysore, Volume I, 1897. At the time that the Kolar Gold Field was beginning to attract attention leases were taken out over the majority of these old workings, but the work done failed to yield promising results and there was a lull in prospecting work. Subsequently, as the results of the work of the Geological Survey, many old workings, not hitherto known, were discovered and for the past ten or twelve years there has been a considerable renewal of activity the results of which have been, so far, disappointing on the whole.

GEOLOGICAL OCCURRENCE OF GOLD.

The gold occurs chiefly in quartz veins and lenses in the Dharwar Schists both in the *lower division* consisting of dark

hornblendic schists and amphibolites and in the *upper division* consisting of greenstones, chlorite schists, calc-chlorite and talcose schists. The former are the most important and include all the mines of the Kolar Field and the Hutti Mine in the Nizam's Dominions which are the principal producers in India. As the two divisions of the schists are not differentiated in the accompanying map the various old workings and places where gold has been found or worked are distinguished by different symbols according to whether they lie in the lower or the upper division. The auriferous veins of the Kolar Field are mainly of a dark bluish or grey colour, but the colour varies greatly and is often nearly white. On this account dark blue veins are usually regarded by prospectors as a favourable indication of gold, but this is by no means a satisfactory guide. Veins of very dark quartz occur in both the hornblendic and chloritic rocks and commonly carry no gold. On the other hand many small rich lenses and stringers of white quartz have been found during prospecting work especially in the chloritic schists. In the Dharwar (Gadag) Field which lies on the northern extension of the Chitaldrug belt practically all of the old workings are in white quartz veins in the chloritic series and the same is believed to be the case on the Anantapur Field. On the other hand the auriferous veins of Kolar and Hutti are of the dark blue variety and lie in the dark hornblendic rocks.

On the whole it is probably a fair generalization to say that the auriferous veins of the lower (hornblendic series) are usually dark, while those of the upper (chloritic) series are usually white or nearly so. In addition there are other veins of dark quartz in both series which are barren and are probably of a different age to the auriferous ones and there are numerous and very conspicuous veins of white quartz in both series and in the gneiss which are also barren and are probably of later age than the auriferous veins as a whole.

Maclaren [1] has noted the above distinction between the

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[1] Notes on some Auriferous Tracts in Southern India. By T. Malcolm Maclaren, B.Sc., F.G.S., Records, Geological Survey of India, Volume XXXIV, Part 2.

auriferous veins of the chloritic and hornblendic rocks and suggests that those of the hornblendic series are much older than those of the chloritic series which latter he conceives to be associated with the great igneous activity represented by the numerous dolerite dykes which traverse the schists and gneisses and therefore of post-archæan age. We are unable to agree with this latter suggestion. It may be true that the dark veins in the hornblendic rocks are older and more crushed than the white veins of the chloritic series, but even this is by no means certain. The degree of crushing is locally very variable in both cases and some of the white veins show considerable signs of crushing and movement and appear to be older than many of the barren veins of quartz and pegmatite which occur in the schists and gneisses and which are intruded by the dolerite dykes. The latter show no signs of crushing or movement whatever. It must be remembered that Maclaren regarded the schists as laid down on, and later than, the fundamental gneiss and was therefore debarred from regarding the latter as a source of the quartz and gold. We take the opposite view as explained in the following section.

ASSOCIATION OF AURIFEROUS VEINS WITH ACID INTRUSIVES.

In Mysore the evidence that the fundamental gneiss—or as we now prefer to call it the Peninsular gneiss—is younger than the Dharwar Schists is so strong that it may now be regarded as established. Further, we have shown that there is a limited gneissic series—the Champion gneiss—which is older than the Peninsular gneiss but still younger than the Dharwar Schists and we regard this Champion gneiss as responsible for the auriferous veins—at any rate for those of the Kolar Field. For this reason the main exposures of the Champion gneiss and its associates have been shown on the map although there may be considerable doubt about the correlation of several of the patches shown. Briefly this old gneiss is a complex of various granites, micro-granites, aplites and pegmatites usually highly crushed and often characterised by blebs of a milky to dark

blue quartz. It tends to pass into finer forms of felsite and quartz-porphyry and isolated exposures of these finer forms as well as some alaskites and finely granular or crushed quartzites are provisionally correlated with it.

The auriferous veins of the Kolar Field are intrusive into the schists and produce contact metamorphic effects which are strikingly similar to those produced by the gneisses, granites and pegmatites (1) and strongly support the view that the auriferous veins are igneous in origin and to be regarded as one of the end-products of a granitic intrusion. Tongues of micro-granite which are regarded as belonging to the Champion gneiss come into the Mysore Mine in close proximity to the Champion Lode and the quartz of the latter has been observed to penetrate these tongues.

On the other hand the great mass of the Peninsular gneiss cuts off both the auriferous schists and the Champion gneiss while the pegmatite veins and cross-courses which cut the Champion Lode are probably products of the intrusion of the Peninsular gneiss. The auriferous veins of Kolar appear therefore to be subsequent to the Champion gneiss and prior to the Peninsular gneiss (or some of it) and in seeking a granitic origin for the gold bearing veins the Champion gneiss appears to offer a handy and suitable source.

Whether we can accept a similar source for the white veins of the chloritic series—the differences in colour, form and degree of crushing being due to the nature of the enclosing rock—is debatable, but it may be noted that recent survey work has been extending our knowledge of the Champion gneiss and that intrusions of it or its associates are now considered to exist in the neighbourhood of the Honnali Field and of the great series of old workings extending from Honnegudda round the south of the Tarikere gneiss to Nandi and across the valley to Ajjampur. In connection with this some work done by Mr. Bosworth Smith during the past two years on the

(1) The occurrence of Secondary Augite in the Kolar Schists. By W. F. Smeeth, M.A., D.Sc., etc., Mysore Geological Department, Bulletin No. 3.

Honnali Field is of great interest. Gold is widely spread in the soil and nullas of that area and examination of a large number of washings led Mr. Bosworth Smith to the conclusion that it was not uniformly distributed but tended to come from certain lines or zones where acid intrusives occurred in the chloritic schists and greenstones. These acid intrusives have been considered by us as probably belonging to the Champion gneiss without our being aware of Mr. Bosworth Smith's conclusions or he of our views and the evidence from the two points of view is independent. No results have been obtained yet but the work will be continued after the war and may prove interesting, not perhaps in the way of disclosing rich ore in any quantity, but possibly in the way of discovering some zones of low grade auriferous lode matter which would permit of cheap working.

There is however ample opportunity for the occurrence of later quartz veins of granitic origin in connection with the intrusions of the various components of the later Peninsular gneiss, to say nothing of possible later or earlier acid relatives of the ultrabasic or other intrusives of the archæan period.

OTHER OCCURRENCES OF GOLD.

In addition to the usual quartz veins in the schists we may refer briefly to various cases in which either the lode material or the enclosing rock presents some special features.

Veins in Trap.

At Bellara in the Tumkur District the old workings and auriferous veins occur in a large mass of trap (hornblende diabase) which is considered to be intrusive into the chloritic series.

At Honmaradi in the north of the Chitaldrug District old workings occur in a grey chloritic trap which has been grouped with the Bellara trap under the name 'Grey Trap,' though it is doubtful whether the former does not belong to the greenstones of the upper division of the Dharwars.

Old workings in Potstone.

At several places old workings occur in the potstone or talc schists which are altered amphibolites and peridotites intrusive into both

the upper and lower Dharwars. Amongst these may be mentioned those at *Chornadihalli* near Sakrebail, some of the workings at *Jalagargundi* and a number of workings on the *Devrukal* block near Yedahalli. There is some doubt about these being gold workings and definite auriferous veins have not been found.

Gold in Ferruginous Quartzite.

The great series of banded ferruginous quartzites has been found to carry a little gold in places and a number of small old workings occur along the ridges of these rocks on the western edge of the Kolar Schist belt. These old workings have not been shown on the map as they are not important. Traces of gold may be obtained by sampling and panning but too small to be worth attention. Veins of bluish quartz occur in the rock and sometimes carry a little gold, but the gold appears to occur also in the banded quartzite itself.

Amongst other places which have been examined the following may be mentioned :—

Shaw's Block; just north of the Kolar-Betmangalam road where three runs of ferruginous quartzite belonging to the western side of the Kolar schists were closely prospected with occasional results up to 10 dwts.

Dindivara; about 12 miles north of Bellara where there are some old workings on two runs of this rock which gave from traces up to a few dwts.

Ajjanhalli; some five or six miles east of Dindivara where a mixed series of ferruginous quartzites and veined chloritic schists gave results up to some 8 dwts. A trial crushing of 200 tons of an average assay value of 3·69 dwts. was made at Kolar and gave an extraction of 1·46 dwts. per ton by amalgamation.

Bodimaradi; about 7 miles N.-W. of Marikanave. This is perhaps hardly a case in point as the old working is in soft ferruginous ochres between two runs of ferruginous quartzite. Prospecting work showed some small irregular veins of quartz

which gave some good assays and parts of the ferruginous country itself gave 3 to 4 dwts. in patches.

Attention has been called to the occurrence of gold in these ferruginous rocks because there is the possibility that somewhere a sufficiently large mass of auriferous lode matter might be discovered which would pay to work even though the average value did not exceed some 3 to 5 dwts. per ton. The nearest approach to this is the result obtained at Ajjanhalli which was not considered good enough to justify further expenditure.

As an illustration of what can be done the case of the Wanderer Mine in Rhodesia may be quoted. Rhodesia is very similar, geologically, to Mysore, and at the Wanderer there are very large ore-bodies composed partly of these ferruginous quartzites and schists and partly of various talc-chlorite-calc schists associated with conglomeratic material which is probably a crush breccia.

Parts of the ore body were 150 feet wide at surface and very cheap open working was possible. Subsequently underground work has been carried on on lode matter 60 to 70 feet in width and mining costs are still very low. The metallurgical treatment is also exceptionally simple and consists of breaking, coarse crushing by rolls and direct cyanide treatment of the product. Assays up to 10 dwts. are sometimes obtained, but the average value of the lode is said to be from 3 to 4 dwts. (Rs. 9 to 12) per ton and the working costs (mining, crushing and cyaniding) a little over Rs. 5 (6*s.* 9*d.*) per ton. Allowing for other charges the work can be carried on at a small profit. In this case we have a very large body of low grade ore which can be mined cheaply and treated very simply on a large scale, and although we have not yet realized these conditions in Mysore the fact that similar classes of material exist leads one to hope that they may yet be found on a big enough scale to justify work.

Gold in Conglomerate and Quartzite.

In the hornblende schists on the south side of the Bababudans north of Chikmagalur there are long beds or bands of quartzite which

we regard as probably intrusive veins or sills. The bottom bed close to the disturbed and faulted junction with the intrusive granite and gneiss has bands of pebbles which may represent zones of crush-breccia. The matrix of the pebbles contains pyrites and is often stained green by copper. Panning showed some gold and a sample of one of the pebbly layers gave an assay of 2 dwts. The extensive exposures and gentle dips as well as the similarity of pebbly portions to such auriferous material as the *banket* of the Transvaal suggested the desirability of further investigation as even a comparatively low grade material would be worth working under these conditions. Large samples were broken from both the pebbly and quartzite bands over several miles of outcrops and a large number of assays made which unfortunately gave no encouraging results. Practically all gave traces of gold and many gave traces of copper also but in no case did the gold amount to 1 dwt. per ton.

Old workings occur in quartzite at *Nandi* south of Tarikere and in the highly quartzose chloritic schists at *Ajjampur* and appear to have been sunk on pipes, pockets or impregnations carrying gold of which no extensions have been found. Below the deepest old working at *Ajjampur* veins of dark blue quartz were found which carried no gold but occasional good assays were obtained from the highly quartzose schists themselves.

At *Jalagargundi*, at a depth of 200 feet an ore body has been opened up which might be regarded as a banded quartzite or quartz-schist carrying calcite, and much pyrites, the banding being marked by brown ferruginous dust. The gold is mostly free and the lode is adjacent to and penetrated by white vein quartz which is barren. The prospects of further work will be referred to later.

Gold in acid intrusives.

There are a few minor old workings in the Champion gneiss itself on the east side of the Kolar Field. At *Ahmed's* Block near Ooregum a shaft in the gneiss showed a small quartz vein 6 inches

thick, but pinching to a stringer at a depth of 55 feet, which gave nearly 4 dwts. per ton.

On the *South Amble* Block, S.-W. of Nanjangud some of the patches of schist held veins of alaskite or pegmatite from which occasional assays up to several dwts. were obtained.

At *Kudrikonda* one at least of the old workings appears to have been sunk on or alongside of quartz-porphyry which probably contained a small pocket or shoot of gold though the trial shaft sunk many years ago is believed to have given no results of value.

These cases are quoted in view of the fact that we have been led to associate many of the felsites, quartz-porphyries and alaskites with the old Champion gneiss the connection of which with the auriferous veins of Kolar has been referred to already.

On the other hand we have no evidence that the great mass of the Peninsular gneiss is auriferous nor have old workings been found in it though some occur in mixed bands of gneiss and schist. We cannot however say that some of the auriferous veins and lenses in the schists may not be end-products of some components of the Peninsular gneiss and it is probable on the whole that the auriferous veins are not all of one age.

Gold in soil and alluvium.

Gold is widely distributed in the soils on the various schists or derived from them and in the alluvial materials along water-courses and river valleys which traverse the schists. Washing has been carried on in the past by native Jalagars or gold-washers but very few of these remain and their earnings are very small and uncertain. They seldom make more than a few annas a day with an occasional lucky find. A few years ago a Lambani found a nugget weighing nearly 4½ ozs. somewhere about Kudrikonda or Palavanhalli, but no further finds have been made although a good deal of washing and prospecting has been done in the neighbourhood. Very occasional results of a few dwts. have been obtained; but on any considerable

scale the results fall within a few grains per cubic yard and the scarcity of water renders the prospects of work practically hopeless.

Some years ago a series of trial pits and washings were made in the alluvium in the bend of the Bhadra river immediately south of the great series of old workings at Honnehatti. There were rumours of good gold having been found there years before and a good deal of gold must have been weathered out and washed away from the surface deposits on which the old workings were made. The trials were a complete failure, very occasional small shows of gold being obtained.

More recently an extended series of tests have been made by the department on the alluvium in and near the bed of the Tungabhadra river, where it crosses the auriferous schists between Shimoga and Honnali. Previous work had shown that gold was distributed in the soil and along small water-courses and the fact of a large supply of water being available rendered a further investigation desirable.

A couple of washing cradles were made and a large number of pits and trenches dug both in the gravels of the river bed and in the alluvium and soil some distance from the banks. Large samples of from one to six cubic yards each were washed and all showed gold, but the quantity was small in every case. An average of all the tests made gives a result which does not exceed 1 grain per cubic yard and the best result obtained was only 3¼ grains per cubic yard. These results are too low to hold out any prospect of profitable working. In the case of the 3¼ grains test, the results would be worth following up if the character of the deposit was favourable, but unfortunately this is not the case as the gold occurs in a hard gravel about 1 foot thick fringing the bed of the river and if it extends laterally beneath the river bank some 10 feet or so of hard clay overburden would have to be removed to get at it. Under these circumstances the prospects of work on a large scale cannot be regarded as encouraging

though it is difficult to understand why the gold should not occur in more highly concentrated patches of workable extent. Similar results have been obtained elsewhere in India and it has been suggested that the seasonal alternations of heavy rainfall and flood with long spells of dry weather are not favourable to the sorting out and collection of the gold in alluvial deposits for which the more or less regular and long-continued action of running water would appear to be essential.

In the foregoing notes we have endeavoured to summarize very briefly the information acquired so far about the gold of Mysore, the nature of the veins or other lode material which carry the gold and the various formations with which they are associated.

In the next section we propose to refer briefly to the more important work done at various points, the character of the work and prospects.

MINING AND PROSPECTING WORK.

KOLAR GOLD FIELD.

It is not possible to attempt any systematic account of the Kolar Mines within the limits of this pamphlet. A general account of the mines and their working, up to the year 1900, has been given by Dr. F. H. Hatch (1); and a few more recent notes and figures will be added here.

The main Champion Lode runs almost continuously through the Mysore, Champion Reef, Ooregum and Nundydroog Mines. In places the quartz has been 30-40 feet wide but the average of the parts worked is probably between 3 and 4 feet, while in places the lode is represented by mere stringers or veined schists or a mere parting of altered schist or lode matter. The quartz sometimes branches and in several places there are one or occasionally two parallel veins from which a good deal of ore has been obtained. The veins strike more or less north and south, but in Mysore there are marked curvatures. The dip, or inclination from the horizontal, of the veins is to the west and is least in the Mysore Mine, where it is about 45°, and increases as we go northwards to over 60°. These figures refer to the upper portions of the mines, down to a depth of 3,000 feet or so, but in recent years the veins have shown a general tendency to get steeper with increasing depth so that at 4,000 to 5,000 feet on the underlie we get dips of 50°-55° in Mysore and of well over 70° in Champion Reef and Ooregum. There are a few large zig-zags which are usually called "folds" though it is probable that they do not represent the actual folding of a once plane sheet

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(1) The Kolar Gold Field, being a description of Quartz Mining and Gold-recovery as practiced in India. By F. H. Hatch, PH.D., A.M.I.C.E., F.G.S., Memoirs of the Geological Survey of India, Vol. XXXIII, Pt. 1,

or vein of quartz and are more likely due to the filling in of zig-zag or branching fissures or dislocations.

The most important feature is the occurrence of the more valuable portions of the veins in patches or shoots with intervening areas of poor quartz or lode matter, and the success of the Kolar Gold Field is due to the fact that these shoots are of considerable size and value and sufficiently numerous to permit of new discoveries being made before the old ones are exhausted. The steady progress of the mines is due not to uniformity in the veins, as the distribution of the gold is very uneven, but to the very extensive exploratory work which is carried on far below the points where ore is being extracted and which permits of work being planned several years ahead of the milling requirements.

In addition to these features the existence of slides or faults cutting the veins has received much attention in recent years, particularly in Mysore and Champion Reef. The great blank in the Mysore Mine between the Ribblesdale and Tennant Sections is due to a great slide slightly oblique to the lode and complicated by others more oblique and it seems probable that the great Crocker's shoot was terminated at its northern end by these slides and not by the natural dwindling of the shoot.

Life of the Kolar Field.

The Field has already yielded gold to the value of nearly £44,000,000 sterling and the nett annual return to the State from royalties and the sale of electric power and water is in the neighbourhood of 30 lakhs of rupees while the yearly wages bill is over 80 lakhs. The question of the continuance of such an important industry is a serious one which is often raised, but anything in the shape of a very definite pronouncement is out of the question.

The auriferous veins lie in a narrow belt of hornblende schists, of about three miles in width, which is cut off on both sides and below by a later intrusive gneiss. The auriferous veins are believed to be older than the gneiss and will

therefore be cut off along with the schists at some depth below surface. This depth represents the ultimate limit of the Kolar Gold Field and we see no reason to apprehend that it will be less than some 10,000 to 15,000 feet from surface and perhaps more. The cut out may of course occur closer to surface, but the above figures are reasonably probable and we need not hunt trouble. The mines have now got down to a depth of rather over 5,000 feet on the inclination of the veins or to a maximum verticle depth of some 4,900 feet from surface. This has taken over 30 years and, if we assume a downward development of 200 feet per annum, we shall have reached a vertical depth of about 8,000 feet in twenty years which is well within the ultimate limit suggested above. It is not improbable that with a low temperature, gradient and efficient ventilation mining can be carried down to 8,000 feet and we need not speculate about greater depths; but it may be noted that down to this depth the whole of the ore will not be worked out in twenty years and that the total period of work will be more probably thirty years. We are assuming, however, that not only do the veins continue, but that the auriferous portions of them or the "shoots" continue to occur with sufficient frequency and of sufficient size to keep up the returns. No one can foresee if this will be so, but, while we see no reason to apprehend any systematic diminution for many years, it would be sound to contemplate reduction of output in the later years.

The problem of the continuance of the Kolar Gold Field is obviously a speculative one and in mining work the more unfavourable contingencies are wont to occur with undue frequency, but we do not see any inherent improbability in assuming that the Kolar Gold Field will continue for another twenty to thirty years, at least, with a probable diminution of output in the later years.

Statistics of production.

In the following tabular statements the yearly output of gold from the Kolar Field is shown from the commencement of operations to the

end of 1914. Small amounts obtained from trial crushings at other mines are also shown.

TABLE 1.—*Gold Production and Royalty.*

Year	Kolar Gold Field £ Stg.	Other Mines £ Stg.	Total £ Stg.	Royalty Rupees
1882 ...	88	...	88	...
1883 ...	96	439	535	380
1884 ...	4,430	332	4,762	3,540
1885 ...	23,989	871	24,860	18,465
1886 ...	63,027	...	63,027	46,785
1887 ...	57,028	...	57,028	42,255
1888 ...	128,879	...	128,879	95,880
1889 ...	298,861	...	298,861	2,22,705
1890 ...	409,449	77	409,526	3,04,620
1891 ...	504,324	...	504,324	3,75,150
1892 ...	622,159	...	622,159	4,62,660
1893 ...	784,842	...	784,842	5,82,810
1894 ...	795,156	...	795,156	5,90,430
1895 ...	973,610	...	973,610	7,23,240
1896 ...	1,228,665	379	1,229,044	9,12,330
1897 ...	1,487,140	92	1,487,232	11,06,790
1898 ...	1,575,966	...	1,575,966	11,70,135
1899 ...	1,678,464	...	1,678,464	12,47,310
1900 ...	1,879,086	...	1,879,086	13,99,980
1901 ...	1,923,130	...	1,923,130	14,28,780
1902 ...	1,964,509	...	1,964,509	14,58,810
1903 ...	2,284,071	...	2,284,071	16,97,085
1904 ...	2,323,195	...	2,323,195	17,26,200
1905 ...	2,373,458	...	2,373,458	17,56,245
1906 ...	2,167,637	324	2,167,961	16,11,390
1907 ...	2,049,064	206	2,049,370	14,96,925
1908 ...	2,055,887	66	2,055,953	15,21,660

TABLE 1—*concld.*

Year	Kolar Gold Field £ Stg.	Other Mines £ Stg.	Total £ Stg.	Royalty Rupees
1909 ...	2,092,459	92	2,092,551	15,49,470
1910 ...	2,107,749	...	2,107,749	17,67,045
1911 ...	2,129,873	...	2,129,873	18,58,845
1912 ...	2,158,362	...	2,158,362	18,85,335
1913 ...	2,150,195	...	2,150,195	18,78,870
1914 ...	2,169,114	...	2,169,114	18,69,490
Total ...	42,463,912	2,878	42,466,790	3,28,11,555

A statement showing the total production from each mine is also given and from the 'Remarks' column it will be seen that most of the less productive mines, which have ceased independent work, have been incorporated with the present working Companies.

TABLE 2—*Total Gold Production of Mines in Mysore, to end of 1914.*

Name of Mine	Bar gold oz.	Value £ Stg.	Remarks
A—Kolar Gold Field—Mines approximately in order from north to south.			
Road Block ...	1,996	7,703	Produced gold during 1898-1901. Included in the Balaghat Block since 1910.
Nine Reefs ...	24,357	92,356	Produced gold during 1887-1890 and 1894-1902. Now included in the Balaghat Block since 1910.
Balaghat ...	433,283	1,642,331	
The Gold Fields of Mysore. ('Golconda' and 'West Balaghat' Mines).	9,496	33,528	Ceased producing gold in 1909. The Company however is in existence.
Coromandel ...	52,940	195,704	Produced gold during 1895-1907. Now included in the Balaghat Block since 1910.
Tank Block ...	117,757	422,870	Produced gold during 1893-1910. The block is included in the Nundydroog Block.
Oriental ...	925	3,526	Produced gold in the years 1901 and 1904 only. Now included in the Nundydroog and Ooregum Blocks since 1910.
Nunydroog ...	1,494,058	5,579,886	
Ooregum ...	1,911,077	7,006,686	
Mysore... ...	4,162,592	16,182,740	
Champion Reefs ...	3,044,674	11,292,209	
South-East Mysore	411	1,303	Originally part of Simons Block known as Rodger's Camp. Now part of the Mysore Block. Produced gold during 1888-1890.
Mysore Reefs ..	699	2,468	Years of gold production were 1889-1891. Now styled 'South Mysore' and is held by the Mysore Gold Mining Co. (1910).
Yerrakonda ...	192	602	Produced gold in 1894-1896. The lease is current and is held by the Indian Mines Development Syndicate.
Total ...	11,254,457	42,463,912	

TABLE 2—*concld.*

Name of Mine	Bar gold oz.	Value £ Stg.	Remarks
	B—Mines outside the Kolar Field.		
Ajjanhalli (Sira Taluk) ...	18	66	Trial crushings in 1908. Abandoned.
Mysore Haranhalli Gold Mine ...	25	77	Trial crushings in 1890. Abandoned.
Kempinkote, Hassan District ...	45	164	Trial crushings in 1896. Abandoned.
Woollagiri Block, Nanjangud Gold Field... ...	203	622	Produced gold during 1906-1909. Abandoned.
Honnali Gold Mining Co. ...	528	1,642	Produced gold during 1883-1885. Abandoned.
Honnali Tribute Syndicate ...	100	307	Produced gold 1896-1897. Abandoned.
Total ...	919	2,878	
Grand Total ...	11,255,376	42,466,790	

A diagram is furnished which shows at a glance the progress of the principal producing mines and of the Kolar Field as a whole. For convenience of space the curve of total production is drawn on half the scale used for the individual mines.

Mining.

For a general account of the methods of mining reference may be made to Hatch's Memoir already cited. As the mines have got deeper, the incline shafts, which followed the trend of the veins downwards, have reached the limits at which it is safe or convenient to use them for hoisting ore for the transport of men and materials. The deepest of these is Carmichael's Shaft, Champion Reef, which is 4,700 feet long. To facilitate work in the deeper levels several vertical shafts have been sunk during the past ten years or so to the west of the outcrop of the lode, of which the principal are the following :—

Edgar's Shaft, Mysore Mine. A circular brick-lined shaft which intersects the lode at a vertical depth of 2,600 feet.

Gifford's Shaft, Champion Reef. Also circular and brick-lined. It is 3,800 feet deep and now practically ready for use. The lode, which has got steeper lies a little to the east of the bottom.

Bullen's Shaft, Ooregum. A rectangular, timbered shaft completed in 1910 to a depth of 3,760 feet. Passed through the lode near the bottom.

Preparations are now being made for continuing work to a much greater depth to provide for which the following shafts have been started recently, all of which will be circular and brick-lined.

MacTaggart's, at the southern end of the Mysore Mine.

Edgar's, Mysore Mine, which is now being deepened to 4,000 feet.

New vertical, Ooregum.

New vertical, Nundydroog.

These shafts will all be about 4,000 feet deep and take some six or seven years to complete. From near the bottom of each, secondary shafts will then be sunk from 4,000 to 7,000 feet or more. The working at these depths will naturally be very hot and much artificial ventilation will be needed. There is no reason to think that work cannot be carried on in these mines to a depth of 7,000 feet or more, and as already pointed out, we see no reason to apprehend any serious failure of the auriferous shoots.

Metallurgical treatment.

More detailed notes on the treatment of the ore for extraction of the gold will be found in Hatch's Memoir (*Op. cit*) and in the Reports of the Chief Inspector of Mines in Mysore for the years 1903-04 and 1911-12.

The practice now followed may be summarized very briefly as follows :—

Sorting and breaking.—The ore is raised to surface and screened to separate the fines from the larger lumps. The latter are crushed in rock breakers to the size of road metal and any pieces of waste rock picked out and discarded. About 18 per cent of the total ore raised is thus rejected.

The ore (fines and coarse) then goes to the stamp mills where it is pounded with water to a fine sand. The fine sand and water is forced by the splash of the stamps through wire screens (900-1200 holes to the square inch) and flows over sloping tables covered with sheet copper on which mercury is spread in a thin layer. The fine particles of gold adhere to the mercury and form with it an amalgam of gold and mercury. The amalgam is scraped from the plates at regular intervals and folded up in a piece of wash-leather in which it is subjected to squeezing. During this squeezing the excess of mercury is forced out through the pores of the leather leaving a hard ball of amalgam inside which contains 40-50 per cent of gold. The balls of amalgam are heated in retorts and this drives off the remaining mercury, leaving a porous mass of 'sponge' gold behind. The sponge gold is melted in

crucibles and poured into moulds thus forming 'bar' gold which is sent to England and refined to get rid of impurities.

Cyanide treatment.—The greater part of the gold is removed by the amalgamating tables, but the fine sands (or tailings as they are called) flowing from the tables still contain some gold (about 3 dwts. per ton) which has not been caught by the mercury. The sands are therefore treated with cyanide of potassium which dissolves the gold; and the gold, or most of it, is recovered from the solution.

The treatment as practiced at present may be roughly outlined as follows:—

The tailings from the stamp mill are put through a series of hydraulic separators and classifiers by means of which they are divided into three grades according to fineness, *viz*:—

(1) Impalpably fine slimes;
(2) Fine sand;
(3) Coarse sand.

The coarse sand is put through revolving tube-mills which grind it finer after which it goes back to the separator where it is divided into slimes and fine sands. The process of separation and classification is a continuous one and the final result is that the tailings are divided into two portions one of which is "fine sand" and the other "slimes" which are treated in separate plants.

Fines and treatment.—The fine sand is placed in large vats each holding one or two hundred tons. The bottom of the vat is formed of canvas filter cloth suitably supported. When the vat is full of sand, cyanide solution is poured in and allowed to stand. The gold is gradually dissolved and when this is complete the solution is drawn off through the filter bottom and water run in to wash out all the gold solution from the sand. The sand is removed from the vat and thrown on the waste dumps.

The gold-bearing solutions are passed through long boxes in which there are a number of compartments filled with zinc

shavings. The zinc causes the gold to precipitate from the solution in the form of a black powder, and zinc goes into solution in place of it. The black powder mixed with remnants of zinc shavings is removed from time to time, treated with acid to dissolve most of the remaining zinc and melted in crucibles with some fluxes. The molten gold is poured into moulds forming bars or bricks of cyanide bar-gold which is also sent to England to be refined.

Slimes treatment.—The special plants for treatment of slimes have been installed within the last couple of years. The slimes are so fine that the solutions could not be filtered through them in percolation vats such as are used for the sands. They are therefore mixed with cyanide solution and agitated, to secure complete solution of the gold, and the mixture of slime and solution (called pulp) is forced or allowed to flow into large rectangular iron tanks in which a great number of filter-leaves are suspended. Each leaf consists of a large flat frame covered back and front with a sheet of filter cloth. A pipe leading from the interior of the leaf, between the two cloths, is connected to a reservoir in which a fairly high vacuum is maintained. When the tank is full a tap is opened connecting each leaf with the vacuum and the solution is sucked through the filter-cloth while the suspended slime gradually forms a cake, one or two inches thick, on the outsides of the filter-cloths. The operation is then stopped, the tank emptied and filled with water to wash the cakes, again emptied and the cakes detached and sent to the waste dumps. The filter is then ready for another charge.

The solutions drawn off through the filter leaves go to zinc boxes and the gold is recovered just as in the sands treatment.

Old Tailings Dumps.

The old tailings dumps which have been through the amalgamation and cyanide processes of former years amount to nearly 10,000,000 tons. The amount of gold which they contain varies very much, some portions running as high as 3 dwts.

per ton while a great deal is under 1 dwt. The new cyanide treatment with its finer grinding and treatment of slimes will permit of the retreatment of considerable portions of the old dumps—probably some three to four million tons—yielding an average of from 1 to 2 dwts. per ton and giving a further return of £1,000,000 and possibly more.

The waste residues under the new treatment will probably be reduced to five or six grains per ton which means an increase in the recovery of gold and of the final output of the Field.

Grade and value of the ore.

The following statement shows the assay value of the ore sent to the mills, and its value in rupees, at intervals since 1898. It will be seen that there has been a steady decrease in the value of the ore mined and by some this would be regarded as indicating an impoverishment of the mines with increasing depth. It would be hard to say definitely whether or not such impoverishment is a fact owing to the very uneven distribution of the ore shoots, but it may be regarded as fairly certain that the mines will become less rich as greater depths are attained. The regular decrease shown in the statement is however very largely due to the fact that working costs have been reduced and that improved methods of extraction have increased the proportion of the gold which can be recovered with the result that large bodies of low grade ore, which would have been left untouched in former years as too poor to treat, can now be mined and treated at a profit. The inclusion of these lower grades of ore along with the richer ore from the shoots lowers the average grade and is a healthy sign of progress and development.

TABLE 3—*Grade of Ore in the Kolar Mines per Ton of 2,000 lbs.*

Name of Mine	1898		1900		1905		1910		1914	
	Grade of ore dwts.	Value Rupees.	Grade of ore dwts.	Value Rupees.	Grade of ore dwts.	Value Rupees.	Grade of ore dwts.	Value Rupees.	Grade of ore dwts.	Value Rupees.
Mysore ...	33·75	101·35	25·53	76·59	19·49	58·47	17·55	52·65	15·67	47·01
Champion Reef ...	30·55	91·65	33·20	99·60	18·10	54·30	11·002	33·016	12·48	37·54
Ooregum ...	16·35	49·05	16·09	48·27	10·35	31·05	12·97	38·91	12·19	36·57
Nundydroog ...	19·49	58·47	22·05	66·15	16·52	49·56	18·14	54·42	18·59	55·77
Balaghat ...	14·23	42·69	19·92	59·76	16·54	49·62	8·26	24·78	8·47	25·41
Tank Block ...	7·03	21·09	5·21	15·63	9·25	27·75	...	...	...	...
Coromandel ...	9·65	28·95	12·81	38·43	7·11	21·33	...	...	...	...
Nine Reefs ...	5·49	16·47	7·70	23·10	...	...	...	...	...	...
Road Block ...	...	...	5·77	17·31	...	...	...	...	...	...
Gold Fields of Mysore ...	...	...	13·76	41·28	...	...	...	...	...	...
Averages ...	23·99	71·97	22·10	66·30	16·53	49·59	14·47	43·41	14·11	42·33

The following statement gives the average working costs on the Kolar Field in the various branches of work. The reduction in costs is marked. Under the head of *mining* are included:—

Working costs.

	Rs.	a.	p.	
Development costing about ...	3	0	0	per ton milled.
Stoping (including timbering)	6	0	0	do
Hoisting do	2	10	0	do

The cyanide treatment now includes (1914)

Treatment of *sands* costing Rs. 1-2-0 per ton treated.

Do *slimes* do Rs. 1-4-0 do

In the last column of the statement the total costs in India, including administration, are given and now amount to about Rs. 19 per ton of ore milled. These however are not the total charges which have to be borne.

We must include about Rs. 2-4-0 for royalty, and Rs. 1-8-0 to 3 for London Office, depreciation, etc., making the total about Rs. 23 or 24 per ton milled. In order to pay these charges the ore must contain an average of 8 dwts. of gold per short ton. This gives us a rough figure whereby to judge whether an ore can be worked profitably or not under conditions similar to those at Kolar. As conditions vary this figure will rise or fall, and the case of the Wanderer Mine (see p. 13) may be referred to as one in which an ore containing some 10 or 11 rupees worth of gold (3½ dwts.) can be worked at a slight profit.

TABLE 4—*Costs on the Kolar Gold Field in Rupees per Ton of 2,000 lbs.*

Years	Mining		Milling	Cyaniding	Total including administration
	Per ton excavated	Per ton milled	Per ton milled	Per ton treated	
1898	13·39	18·00	3·81	2·01	25·77
1900	12·99	17·79	3·80	1·74	25·98
1905	9·78	13·38	2·39	1·16	18·51
1910	9·02	13·65	1·86	1·17	19·98
1914	8·76	12·66	1·75	1·20	19·56

With the foregoing brief account of the work being carried on by the leading mines of the Kolar Field we shall now pass on to the work done and prospects in other areas of the State, taking up the various schist patches or groups of workings seriatim. The information about some of the earlier work is often scanty, but since 1898 the principal workings have been inspected and reported upon by the Director and other officers of the department. Further details than can be given here will be found in the Reports of the Chief Inspector of Mines and for convenience of reference the dates of these reports will be given where necessary in the text in square brackets.

Before leaving the Kolar Field a few remarks may be made about prospects at the north and south ends of the Field.

New Kempinkote.—This property lies immediately south of the Mysore Mine from which point the auriferous schists extend south for a couple of miles before they are cut off by the Champion gneiss. In the early days of the Field much work was done here to a depth of several hundred feet and small patches of good ore obtained. The country is much disturbed and no large shoots were found. During the past two years work has been started to test the ground at greater depths by driving southwards from the 2,160 and 2,385 foot levels of the McTaggart's Section of the Mysore Mine. Some quartz up to 9 dwts. in value has been found, but nothing big or continuous and it is to be hoped that the work will be pushed on as far as possible as any success here would lead to the opening up of a considerable area of schist which is certainly auriferous.

The Balaghat Mine.—This occupies the whole of the northern end of the Field and includes the former Balaghat property as well as those of Road Block, Nine Reefs and Coromandel in which a number of shoots have been worked in past years on two or three lodes which may be regarded as discontinuous extensions of the Champion Lode Series. Recent developments in the bottom of the Balaghat Mine

have been encouraging and may lead to extension of work southwards below the old Coromandel Mine. The developments northwards from the Nandidroog Mine in the lower levels of the former Tank Block and Oriental properties point in the same direction, and thus there are fair prospects of a considerable area of ground being opened up between the Oriental workings of Nandidroog and the new finds in the bottom of Balaghat.

About half a mile west of these lodes are the Oriental and West Balaghat lodes on which much work was done by the Road Block, Nine Reefs and Gold Fields Companies but which have now been abandoned.

Ahmed's Block.—This lies on the east of the Nandidroog Mine where there were some doubtful old workings. Half a dozen shafts were sunk, the deepest being 118 feet. Of these 4 were in the Champion gneiss and 2 in hornblende schist. Shafts Nos. 1 and 2 are in the gneiss. In No. 1 at a depth of 90 feet levels were driven for 80 feet on a vein which is said to have carried gold, but samples taken by Mr. Bocquet did not give more than 6 grains. In No. 2 there is a small quartz vein which is only 1 to 2 inches wide at the bottom and gave an assay of nearly 4 dwts. The work was inspected and reported on [1907-08] and the prospects were not sufficiently favourable to justify further expenditure.

KOLAR SCHISTS NORTH OF THE KOLAR FIELD.

Krishnarajpur.—Immediately north of Balaghat (Road Block) some loose quartz on surface showed gold and it was thought that this might come from an extension of the Balaghat lode. In addition to some shallow shafts and drives a shaft was put down over 300 feet and a cross cut started east. Nothing was met with and work was abandoned in 1899. Considering that some 4 or 5 lakhs were spent in machinery and sinking it is a pity that the cross cut was not extended further for the sake of exploration at the depth reached.

Plantation Block.—Lies to the west of Krishnarajpur and contains some dumps and filled-in old workings. Prospecting work has been taken up from time to time without success. At the present time work is going on at three small shafts on filled-in old workings and although nothing of importance has been met with it is probable that at least one of these points will be further explored.

East Betarayaswami.—A large block on the north of the two former. Prospecting work was started over ten years ago by Mr. Mervyn Smith who opened a large number of pits and trenches on a lode formation running through the eastern side of the block which was regarded by him as a possible extension of the Champion series. In many places vein quartz or lode formation on two parallel lines was opened up but the panning and assay results were poor.

Some distance to the west some old workings were opened up and a couple of shafts sunk to test the old workings. A level at a depth of 150 feet passed through some of the old workings and is reported to have given good values for about 150 feet south. Further work has been done recently by the East Betarayaswami, Limited, Syndicate, and the main shaft sunk to a vertical depth of 454 feet. Long drives at the 300 and 440 foot levels have opened up a well defined vein of quartz, which, for the most part, assays very low. At the 300 foot level quartz assaying from 5 to 30 dwts. was passed through for a length of 20 feet and it is evident that the shoot on which the old workings were made has dwindled and vanished in depth. Further work is in progress from the 440 foot level in the hopes of striking a new shoot in the quartz.

Shaw's Block (*Badamakanhalli*).—North of the last block and just north of the Kolar-Betamangalam road where the schist belt is narrow. Extensive prospecting work was carried out by Messrs. Shaw Wallace & Co. in 1907-08 and the work inspected and reported upon [1907-08]. Many thousand feet of trenches were made and 8 shafts sunk up to 71 feet in depth. Three lodes of ferruginous quartz schist were

disclosed and numerous veins of bluish quartz most of which showed traces of gold but none of them carried payable values. The ferruginous quartzite carried a little gold in places as also did the quartz veins which penetrated them. The eastern or 'schist' lode gave the best results. It is 3 to 4 feet wide at surface and gave assays from a trace to 8 dwts. At a depth of 60 feet it had narrowed to 18 inches and gave from a trace to 4 dwts. Work was stopped in 1908 as there was no indication of any body of payable ore.

Jayamangalam.—This lies north of Shaw's Block and some deep prospecting is reported to have been done about twenty years ago. An incline shaft was sunk to a depth of 80 feet on an outcrop which is stated to have given 4 dwts. This result has not been confirmed since and the results obtained on sinking were practically valueless.

A few small old workings have been found north of Jayamangalam in the neighbourhood of Holali and Vitpalli, but washing of the dumps and float quartz gave practically no gold.

Manighatta.—North of Vitpalli the schists widen again to a large body and washings in the streams near Manighatta and Shagatur, frequently gave shows of gold. The area was examined by Mr. Lavelle and a number of trenches put in which disclosed many veins of quartz some of which panned gold. There is a large old working to the east of Manighatta village with a smaller working to the east of it. No other old workings are known and the isolated character of the large pit rendered people shy of spending money on it. In 1910 Captain Lethbridge started work on behalf of the North Kolar Syndicate and several shafts were sunk to a depth of 60 feet both close to the old working and on some of the veins disclosed in trenches to the north of it. The work was reported on [1911-12] and further work recommended which was carried out, under option by the Ooregum Gold Mining Company in 1911-12. The earlier part of the work showed that the old working was 30 feet wide at the north end at a depth

of 60 feet but there was no shoot or vein continuing northwards. At the south end a small shoot of rich quartz was found but this vanished into valueless stringers a few yards to the south. The later work done by the Ooregum Company consisted in sinking a vertical shaft, 210 feet deep, to the west of the old pit, from the bottom of which a cross cut was driven east under the old working but failed to find any quartz of value. Another cross cut was put in at the 118 foot level and intersected a small vein below the south end of the pit. This was driven on north and south for about 145 feet for the greater part of which the vein averaged about 15 inches of quartz with about 6 dwts. of gold and this increased to 18 inches and 15½ dwts. in a rise up to the old working. At the north end of the level the quartz went into stringers, but in a winze below 6 inches of quartz assaying 14½ dwts. of gold was found.

The general results show that the old working was of considerable width and about 150 feet long. It may have been sunk on a large lens of quartz or bunch of veins but the quartz does not continue north and south. Some of the quartz is left below the old working and this thins out and decreases in value at 118 feet. There is no trace of it at 200 feet.

After a careful examination it was suggested that the vein may have been faulted to the east between 118 and 200 feet from surface though this is very doubtful. The results obtained are not encouraging, but some further work might be recommended in continuation of the winze at the north end of the 118 foot level to see what becomes of the vein and whether it opens out again along a northerly pitch.

The large area of schist in which the Manighatta old working is situated is very similar in character to the Kolar Field and carries numerous quartz veins which are slightly auriferous. The marked absence of old workings is an unfavourable feature and means the absence of specific points for the start of prospecting work. Trenching has not led to any discoveries and it is only on account of the similarity of the

country to that of the Kolar Field that one might be tempted to suggest a purely speculative effort, to the extent of 5 lakhs or so, to be spent and a widely spread series of trenches and small shafts and cross cuts. It is possible that the extensive capping of laterite and laterite soil may conceal valuable outcrops which under other circumstances would have been marked by old workings.

THE CENTRAL OR CHITALDRUG SCHISTS.

The various points at which work has been done in the Chitaldrug Schists will be taken in order from north to south.

Halekal.—East of Davangere. Mr. Bruce Foote observed numerous dumps between the village and Halekalgudda and considered that the surface soil had been largely turned over. During survey work in 1903, Mr. Slater found some old workings on Halekalgudda and some prospecting work was done between 1907 and 1909, under prospecting license No. 100 without success. Traces of gold were found down to a depth of 70 feet, but no auriferous veins were discovered. The old workings appear to be in or adjacent to quartzite and have been examined more recently (1915) by Mr. Coleridge Beadon, who did not consider them worth further attention.

Honnemaradi.—South-east of Jagalur where Bruce Foote reported the existence of fine reefs and veins of quartz. In 1905, Mr. Sampat Iyengar discovered an old working which is reported to be in the grey-trap of Chitaldrug. A prospecting license was taken out by the Madras-Mysore Mining Syndicate in 1907, but no encouraging prospects were found.

Kotemaradi and Gonur.—North-east of Chitaldrug. A number of old workings were noted by Bruce Foote and a mining lease taken by General Cole in 1890. No records of any work done are available, but some of the pits were examined in 1897, by Mr. Sambasiva Iyer, who found gold in the surface materials and in 1906, several of the pits and burrows were examined and prospected by the department. Two were found to be irregular tunnels about 25 feet in length

and two were open pits. None of these showed any defined vein or lode, but the schist contained many stringers of quartz which assayed nil. Washings of the earth from the sides and bottom showed a little gold as also did those from the nullas to the north of the workings. Subsequently a license was taken out by the Madras-Mysore Mining Syndicate and a small shaft sunk and an adit driven for 60 feet without obtaining any results of value. A considerable amount of work was also done in the hills east of Chikannanhalli a few miles to the north.

In the central body of the schist between Hiriyur and Huliyar a large number of old workings, not previously known, have been found during the course of survey work by Mr. Sambasiva Iyer and by Messrs. Wetherell and Sampat Iyengar and the presence of gold ascertained by washing the dumps and materials from the pits. Subsequently the majority were closely prospected by Mr. Randolph Morris and others and a number of licenses and leases taken out by him and by the Indian Mines Development Syndicate. The chief points worked are the following:—

Bodimaradi.—About seven miles north-west of Marikanave. An old working was found by Mr. Sambasiva Iyer on the flank of Iplara hill. It is a deep narrow excavation, bands of limonite with veins of powder quartz lying between in earthy ferruginous quartzite.

An adit has been driven through the western bed of quartzite and south through the limonite passing through and beyond the old working and at the south end a winze has been sunk about 100 feet and some short levels driven. It was expected that the run of stuff which the old workers followed would be met with in the winze, but nothing satisfactory was encountered. A stringer of rich quartz was passed through but led to nothing. An interesting feature is the fact that the limonite itself showed some 3 or 4 dwts. of gold very consistently over width of about 8 feet for a short depth, but this was not found to continue at the lowest level reached. [1903-04.] The work was abandoned in 1904.

To the south of Javangondanhalli, a number of blocks were taken up and much work done at several points of which we may mention the following :—

Javanhalli Block.—The workings are in hornblende schist with some dark chlorite schist. Several shafts were sunk up to 200 feet in depth and a number of drives and cross cuts put in to test the ground beneath the old workings but in no case was any payable vein or lode found and work was suspended in 1908. [1907-08.]

Annesidri.—The workings are to the west of Javanhalli and also lie in hornblende schist. No valuable results were obtained.

Ramanhalli and *Ajjanhalli.*—These lie five or six miles to the south of the above in the chloritic schists. Little work was done at Ramanhalli as the surface prospects were not encouraging.

At *Ajjanhalli* extensive adits and cross cuts were made in the Gavigudda hill in which a very considerable ore body was met with at depths of 100 to 300 feet. The main adit is over 600 feet in length in ferruginous quartzite which gave assays from ¼ to 6½ dwts. In the main cross cut east for about 150 feet the mixed chlorite and ferruginous schists gave assays of from 4 to 8 dwts., but the values sank to 1 dwt. or less in the cross cuts to the north and south of this. The work disclosed a very considerable body of schistose lode matter which was very carefully sampled and a bulk sample of 200 tons sent to Kolar for treatment. The average assay value of the bulk sample was 3·69 dwts. but the mill extraction was only 1·46 dwts. per ton.

These results were not considered good enough to warrant further work but they are more encouraging than have been met elsewhere in this area and might be deserving of further attention. [1907-1908.]

Dindivara.—Some pits which were considered to be old workings were found on two runs of ferruginous quartzite south of Dindivara village about six miles west of the above

series of workings. Mr. Bosworth Smith took out a license in 1907, and put in a number of pits and trenches from which small values were obtained and he considers that the gold is in these ferruginous quartzites as well as in the quartz veins in them. The gold was very small in quantity and appears to be less in depth than at surface.

Bellara.—Work was carried on for several years by the Indian Mines Development Syndicate in connection with some old workings originally found by Mr. Sambasiva Iyer and subsequently prospected by Mr. R. H. Morris. They are in a large mass of altered diabase which intrudes the chlorite schists. The principal workings are on a small hill where there is an outcrop of quartz (Bellara reef) which gave some good shows of gold on panning. Three shafts were sunk and levels driven at 130, 230 and 330 feet. There was a good vein of quartz but the values were very low and work was stopped in 1905. At the western foot of the hill what is known as Tank reef was located after a considerable amount of prospecting, and found to be dipping west. Altogether ten shafts were sunk over a length of about 2,000 feet. The deepest was a little over 400 feet and a number of levels from this and other shafts disclosed the existence of a quartz vein varying from a few inches to two and a half feet in width which assayed from a trace to about three ounces with occasional richer patches. A considerable proportion could be taken out at an average of 9 dwts. or so, but the total tonnage is too small to justify the erection of a plant. At the deepest point the quartz was nearly 4 feet wide but of no value and at other points the values at depth were all small. At one time the results appeared to be quite promising, but the poor results obtained in depth caused the mine to be abandoned.

In the southern portion of the Chitaldrug schist belt and in the outlying stringers near it, several old workings and dumps have been noted. A large number of leases were taken up in the early days, but no promising results were obtained and very little work done. The following may be mentioned:—

Honnebagi.—East of Chiknayakanhalli. There are a number of shallow workings near the edge of the schists which are partly hornblendic. Some trial pits on the quartz veins gave no gold.

Kalinganahalli.—Just south of the Kunigal road. There are a number of dumps from which gold can be washed and probably represent the turning over of the surface soil and debris.

Nagamangala.—On the outlier of hornblendic and talcose schists west of the town there are numerous quartz veins which were favourably noticed by Mr. Bruce Foote. Little work appears to have been done on the old leases which have since been abandoned. A number of these veins were sampled by Mr. Wetherell during survey work but gave nil to traces of gold with sometimes 1 or 2 dwts. of silver; and further work does not seem to be advisable.

Hunjankere.—On a small patch of hornblendic schists about 7 miles east of Seringapatam. There are a few old workings here which were tested in 1907 by Mr. J. G. Hooper under an existing lease [1906-07]. Several shafts and trial pits were sunk and three quartz veins tested one of which gave occasional assays up to 10 dwts. The country and lode matter is rather like that at Woolagiri, but on a small scale and no indications of any body of ore were found.

Butgahalli.—North of Bannur. There are some old workings here on a small patch of hornblendic schists. These were prospected by the department in 1905-06 and two shafts sunk and several trenches made. Some small shows of gold were obtained but nothing sufficiently encouraging to warrant further work. An extended series of alluvial washings were made at the same time at Hunjankere but gave only minute traces of gold.

WEST CENTRAL SCHISTS.

A number of old workings have been recorded along a stretch of country in the Hassan and Mysore Districts from

Banavar to south of Nanjangud. The positions of these are shown on the map. They lie in small shreds or patches of hornblendic or talcose schist or schist and gneiss and many of them appear to be unimportant and have failed to attract serious attention. On the more important or promising looking a good deal of work has been done of which the following is a brief record:--

Yelvari.—Near Haranhalli. These were tested by the Mysore-Haranhalli Gold Mining Company in 1889-1890. A trial crushing of a bulk sample of the stone appears to have been made from which 25 ozs. of gold were obtained, but the results were too poor to justify further work which was suspended in 1890 and the Company transferred its activity elsewhere.

Kempinkote.—(Hassan). They lie on an isolated patch of hornblendic and talc-chlorite schists to the south of the Nuggihalli schist belt where there is a very large old working (over 600 ft. in length) with a smaller working to the north of it. The property was taken up by the Kempinkote Gold Field, Ld., with a capital of £170,000 and a great deal of work was done from 1893 to 1896. The ground beneath the old workings was tested by two shafts to a depth of 500 feet, several thousand feet of drives and cross-cut being put in. No very definite vein of quartz or fissure lode was found, but a wide zone of auriferous schists with numerous veins, bunches and lenses of quartz was disclosed which is stated to have been 70 feet wide in places and sometimes up to 150 feet in width with intervening schist bands. Much of the quartz, especially in the large veins, was very poor, but the banded schist formation sometimes gave an average of 8 to 10 dwts. for considerable distances and widths. The occurrence of rich pockets assaying up to 10 ozs. was a noticeable feature and helped to raise the average of some of the drives, but they were too few and far between to produce any considerable or reliable influence. A great deal of the lode formation went under 1 or 2 dwts. in value and the formation appeared to be

narrowing in depth. Taken as a whole the formation is of low grade and if taken out in bulk the average would probably not exceed some 2 dwts. per ton. We believe that this represents the opinion of Mr. R. H. P. Bullen who was in charge of the work and that there is some prospect that the grade might be improved somewhat by selection or sorting. There is some reason to hope that the property will be taken up again and given a further trial in view of the improvements in treatment and extraction which have taken place in recent years. If sufficient material could be obtained to give an output of 100 to 150 thousand tons a year of an average value of 5 dwts. or so and with a simple process of extraction the prospects of working at a profit would not be beyond hope.

Bellibetta.—There are a number of workings in outliers of the schists to the west of Krishnarajpet. Of these the most important are on the Bellibetta hill and several mining leases were taken out in 1886. Little work appears to have been done, but in 1901-02 an option was acquired by the New Kempinkote Company and some shafts sunk to test the reefs which the old workings are supposed to have followed. The quartz was practically valueless. Washings from the dumps and assays of float quartz gave small shows of gold which in no case exceeded 1 dwt. per ton.

In the Mysore District there are several old workings in the neighbourhood of Hunsur and Nanjangud. Of these the most important are those at Woolagiri (Volgere) and Amble and a large amount of money has been spent from time to time in testing them and the schists in which they lie and they have been closely examined and reported upon by the department.

Amble.—On this block the old workings were tested about 1895 by a small Syndicate and some good specimens obtained. In 1899 to 1901 work was taken up by the New Kempinkote Company and at North Amble shafts and levels to a depth of 178 feet disclosed a quartz vein about 5 feet in width which was auriferous, but the values were low and seldom ran above 4 or 5 dwts. At South Amble sinking was continued to a

depth of 200 feet, but with the exception of a small vein below the old working which assayed a few dwts. nothing was found. A large vein of pegmatite was encountered which gave assays as high as 15 grains per ton. A great many trenches and pits were made all over the strip of schist and many of the quartz veins and alaskites were found to contain small amounts of gold but nothing of any value for mining. [1901.]

Woolagiri.—A large old working lies to the north of Amble workings in a separate patch of hornblendic schist. Early work is said to have yielded some rich samples from a shaft 96 feet deep from which a cross-cut was made beneath the old working. In 1906 work was taken up by the Nanjangud Gold Field and levels, etc., driven at 96 and 126 ft. disclosing a complex lode of quartz and altered schist over 20 ft. wide. The mine was sampled and reported upon departmentally the result of which was to show that the lode averaged about 4 dwts. of gold per ton about 1/5th of which is in pyrites. [1901 and 1906-7.] This is too low to pay and it was suggested that much of the lode material (white quartz, granite, etc.) could be picked out raising the remainder to from 7 to 10 dwts. and that if a sufficiently large body could be proved it might be possible to make it pay. A vertical shaft to a depth of 200 ft. was recommended and exploration at that level to see if the lode continued or improved. This work was carried out, but it was found that the lode had narrowed considerably in depth and that notwithstanding some bunches of good ore the average value was low.

A five-head stamp mill was put up and various trial crushings made from 1906 to 1909. The trials on the general samples of ore sent to the mill averaged 3·26 dwts. of bar gold per ton and on picked ore 5·07 dwts. The tailings probably averaged about 1·5 dwts. per ton.

The mine was finally reported upon by Mr. Bosworth Smith (1) in 1913 on behalf of the Eastern Development

(1) Mysore Geological Department, Records, Vol. XIII p. 157.

Corporation and as his report was unfavourable work has been abandoned.

HONNALI GOLD FIELD.

This first attracted attention in 1880. A large number of leases were taken out in the neighbourhood of Kudrikonda and Palavanhalli and were acquired by the Honnali Gold Mining Company with a capital of 4 lakhs of which about 2 lakhs was available for working. Owing to the prevalence of gold in the soil, some rich float quartz and some very high values were obtained during prospecting work. Very sanguine reports were drawn up and a good deal of money was spent on a 10-head battery, percussion tables, reverberatory furnace, arastras, etc., before the value of the ore bodies were proved. The final result was a shortage of money which might have been more usefully spent in further exploration. The principal work was done at Kudrikonda where there were some old workings most of which were proved to be erratic and not very deep. At the main shaft a reef called Turnbull's reef was opened up to a depth of 165 feet and found to be a lenticular shoot pitching north with quartz up to 5 feet in width which pinched into stringers towards the bottom. Four other shafts were sunk on the lode to the north of the main workings but gave poor results. The main shoot appears to have contained very rich patches, up to 35 ozs. to the ton, but the average result was quite low. Altogether 2,586 tons of quartz were obtained and yielded 528 ozs. of gold, or an average of about 4 dwts. per ton. This average is too low to pay and the quantity of ore to be obtained is apparently small. A report of the Honnali Company published in 1885 sums up the results of working by saying that each ounce of gold had cost the Company Rs. 139-10-5, while its sale value was only Rs. 45-9-9.

Funds being exhausted the mine was closed, but shortly afterwards The Honnali Tribute Syndicate started further work most of which was carried out by Mr. James Young who has kindly furnished the following particulars :—

The North Air Shaft, which lies 160 feet north of main shaft and had previously reached a depth of 90 feet, was continued to 260 feet and several short drives and cross-cuts put in. At 150 feet the reef improved to 4 feet in width and showed gold estimated at from 18 dwts. to 34 ozs. per ton. At 164 feet it passed out of the shaft. At the 200 feet cross-cut only stringers were found, but in a drive north some small quartz is reported to have been several ounces in value. About 130 tons of quartz obtained during these operations were put through the mill and yielded 100 ozs. of gold. Notwithstanding some high values the work done failed to reveal any valuable body of ore and the mine was finally closed down although Mr. Young was still very sanguine about finding something more substantial with further work.

There can be no doubt about the existence of small rich lenses and patches in this field and that others would be met with if the workings were considerably extended. Unfortunately a few rich patches do not make a mine and the cost of finding them and extracting the gold is likely to exceed the value of the gold won as shown by the milling results of the Honnali Company.

On the other hand these isolated patches may easily account for the prevalence of gold distributed through the soil of the area as many of them must have been exposed and broken down, with resultant separation of the gold, during the long denudation of hundreds and probably thousands of feet of the schists in which they occur.

The number 15 Honnali Gold Mining Company.—Opened a mine about 1 mile north-west of the Honnali Mine, to a maximum depth of 315 feet. The veins and stringers were poor. The best result appears to have been a vein 18 inches wide worth 4 to 5 dwts. which was found in the north level from Air Shaft.

Palavanhalli Gold Mining Company.—The Company did some work at a point four miles south-east of the Honnali Mine, where there is a shallow old working. A main shaft was

sunk to 100 feet on a cross-cut east driven but no ore of value was encountered.

After a long period of inactivity some further attention has been paid to this field during recent years. Numerous washings and trial pannings have been made by the department without locating any promising material.

Under prospecting licenses held by the Eastern Development Corporation a considerable amount of prospecting has been carried out under Mr. Bosworth Smith which has been referred to already (p. 11) and which will be continued.

On several other blocks in the neighbourhood of Palavanhalli a good deal of work was done a couple of years ago on behalf of some of the Kolar Companies, but the results were poor or nil and the licenses have been given up.

SHIMOGA-TARIKERE GROUP.

A reference to the map will show that a very large number of old workings have been found in the schists around the Shimoga and Tarikere masses of granite and gneiss. In these schists some runs of fine granite, quartz porphyry, quartzite and crush breccia or conglomerate have been found and are regarded as probable representatives of the Champion gneiss.

At Honnehatti, Nandi, Ajjampur and Bukkambudi the old workings have been known for a long time past, but a very much larger number were discovered subsequently—chiefly by Mr. H. K. Slater—during the course of survey work.

The following is a brief account of the mining and prospecting work at the principal points starting from the west side of the group.

Chornadihalli.—These workings lie about eight miles south of Shimoga. Mr. Slater found a large number of pits over a considerable area both in the chloritic schists and in the potstones. The area was prospected and reported upon [1906-07] by Mr. Balaji Rao who obtained indications of gold from some

of the pits and adjacent nullas. No auriferous quartz was found and it is possible that many of the pits were not for gold. The prospects are not promising and no serious work was attempted although a prospecting license was taken out and held for several years.

Honnehatti.—South of Benkipur and close to the Bhadra river a very large number of old workings occur on the Honnegudda hill and on the flats to the south of it. These have attracted a great deal of attention since 1887 when a lease was taken out by the Mysore-Nagar Gold Mining Company. In more recent years the ground has been extensively prospected under Mr. Bosworth Smith and Capt. Lethbridge and the results may be summarized as follows:—

In the saddle on the Temple Hill are large old workings which were tested by an adit driven into the hill for 294 feet and from which a rise was put up into the old workings. A lode formation was found consisting largely of massive quartz with pyrites and on this some levels were driven and a winze sunk to 74 feet below the adit level. The samples showed that the lode or vein averaged about 2½ dwts. per ton, the highest assay being 8 dwts. The pyrites carries gold to the extent of about 12 dwts. per ton. This material was obviously unworkable and attention was directed to the low ground between the hill and the river.

In this ground there are a very large number of old workings spread over a large area, the principal ones being grouped along three parallel lines. One or two of these are more than 50 feet deep, but the majority are much shallower. The Mysore-Nagar Company sunk two shafts and put in some pits and trenches but the results were poor.

The No. 1 shaft was 100 feet deep and in a cross-cut west at 80 feet a vein eight inches wide assaying 2½ dwts. was found. Nothing of value was found and as water was heavy work was stopped.

The White Cedar shaft was sunk for 95 feet and at 83 feet a drive was put in just below the old working. Stringers

and veins of quartz were found which occasionally showed gold, but the average results were very low.

Mr. Bosworth Smith reported on the property in 1903 and found that the mineralized lode from the bottom of White Cedar shaft gave about 3½ dwts. and from the drive at 83 feet some 7½ dwts. He also found that picked samples rich in sulphurets (iron and copper pyrites and blende) gave 14 to 17 dwts. and that the concentrates from these gave about 2 ozs. per ton. He formed the opinion that although there may have been a good deal of free gold in the broken-down and weathered materials near the surface, on which a large number of the shallow old workings were made, at greater depths the greater part of the gold was in the pyrites and that the ore would be refractory and require concentration. He thought that considerable bands of mineralized lode matter (quartz and schist) might be found which would pay to extract.

Subsequent work has not disclosed any considerable lenses or bands of payable material although several thousand feet of trenches were put in and a large number of pits sunk on veins which showed from a trace to 20 dwts. to the ton, but which invariably pinched out or became poor in depth. The results have been very disappointing but it may be noted that Mr. Bosworth Smith's main recommendation was not carried out. This was to sink a shaft to 300 feet a little west of the White Cedar shaft and ascertain whether any sufficiently large lenses or bands of heavily mineralized lode matter were to be found below water level. The expense of the necessary plant and the poor results already obtained no doubt accounted for this, but it is possible that some one will still have the courage to carry it out.

Tambadihàlli.—Around Tambadihalli and Shinganmane many old workings have been found in the jungles—mostly nearly filled in and covered with soil and leaves. Work was carried on for several years by the Shimoga Gold Fields, details of which will be found in the Mines Reports for 1906-07 and

1907-08. At seven different places shafts were opened up to a depth of 100 feet or so and drives put in. In three or four places rich stringers and lenses of quartz were found running several ounces to the ton; but in no case did any of them continue for any considerable distance or make into a workable body of ore.

Teak Plantation Block.—Some work was done in 1908-09 on the old working here which was unbottomed. It was found that the pit had been sunk on a small rich shoot of quartz which had a length of about 40 feet and carried several ounces of gold and no pyrites. At 20 to 30 feet below water level the shoot had shortened to 20 feet and was evidently pinching rapidly and as the water was very heavy, work was stopped. It is a point which will doubtless be attacked again if the neighbouring workings at Jalagargundi are reopened and staff and machinery are available.

Jalagargundi.—This is the most important point in this group. There is one very large pit and a number of smaller ones scattered about in chloritic and talcose schists and potstones. A large amount of work has been done [1907-08; 1908-09]. No. 1 shaft was sunk to a depth of 230 feet close to the large pit and some quartz about two feet wide, said to be worth 15 dwts., was found at about 160 feet. At 190 feet the quartz was wider, but carried only from a trace to 4 dwts. At No. 2 shaft, a lode was cut at 170 feet said to be worth 15 dwts. and 10 or 12 feet wide. At 200 feet it is about 11 feet wide and said to be of fair though variable value. In a drive to the west the lode became poor, but for 105 feet to the east it was estimated to be worth over 1 oz. In 1913 the lode along the east drive was stoped out for 150 feet for a height of 5 feet of which a general sample gave just over 10 dwts. By picking out the white barren quartz the balance (69 per cent) gave an average of nearly 14 dwts. [1913-14].

The lode is a sort of finely granular and banded quartz schist with some calcite and chlorite and fine parallel lines of oxide of iron dust. Alongside and penetrating it is a large

blow or vein of white glassy quartz which is barren. The gold is mostly free and the lode is richly studded with small crystals of pyrites which carry little if any gold. Work is stopped at present, but it is expected that fresh funds will be forthcoming to continue operations.

Shiddarhalli.—The old workings are on the crest of some low hills and at the bottom of the principal working the lode which was mixed quartz and schist gave some 4 dwts. per ton. An adit was driven from the north face of the hill and cut the lode formation at 291 feet about 100 feet below surface. The lode was driven on for 120 feet east of which the first 50 feet was on an average 5 feet wide and about 9½ dwts. in value and from there to the end about 6¾ dwts. and getting narrower and finally splitting up. The west drive disclosed a body of ore 5 feet wide giving assays of from 6 dwts. to 1 oz. with an average of 12½ dwts. At 45 feet a cross lode carrying graphite was met with, beyond which the main lode narrowed from one foot to stringers in a distance of 15 feet. Several other drives were put in showing low values and levels were driven at 75 feet below the adit level which showed very crumpled and disturbed country and practically no lode formation of any value. Work was suspended in 1913 as results did not justify further expenditure, the small run of ore below the old workings having disappeared in depth as well as east and west and the country being too disturbed to hold out much hope of picking up any continuation of it.

Nandi (*Hoshalli*).—A few workings occur between Shiddarhalli and Nandi Hill, south of Tarikere, but nothing has been found by the prospecting work done at several points. The old workings at Nandi and Chattanhalli were prospected departmentally by Mr. Primrose in 1897 (Records Volume II, pages 57-61) who found little except small shows of gold in some of the nullas. Since then the ground has been held under a mining lease and two of the workings on Nandi Hill cleared out to depths of 120 and 210 feet. The assays did

not exceed a few dwts. and the prospects have not been considered sufficiently good to warrant much expenditure and comparatively little work has been done. Recently [1912-13] one of the workings on the west side of the Tarikere road was tested by a vertical shaft to a depth of 198 feet and some quartz veins of little value found.

To the west of the long series of workings described above some others have been found at *Hoshalli* and *Devrukal* (Aramballi) not far from Yedahalli. Those at Hoshalli are in dark hornblendic rocks and amphibolite and the pits and trenches disclosed little of interest with the exception of a vertical vein about 4 inches wide giving assays up to 10 dwts. but showing no tendency to widen out.

At *Devrukal* the workings are in potstone and talcose schists. The dumps gave hardly any traces of gold and a long adit driven below the largest pit failed to find any lode of value. It is by no means certain that these workings were for gold, but no other mineral has been observed with the exception of a little chromite.

Ajjampur.—Passing to the north side of the Tarikere gneiss we come to some old workings on the hills to the west of Ajjampur. These were described by Mr. Sambasiva Iyer in 1897 (Records, Volume I, page 92) and the subsequent work inspected and reported upon by Dr. Smeeth [1901]. The workings are in a series of chloritic and felspathic quartzites or quartzose schists which are now thought to be associated with the Champion gneiss. There are two large pits named *Hondonna* and *Hakkidonna* and a good deal of work was done by the Kadur-Mysore Gold Mining Company. *Hondonna* lies a little north of the temple on the top of the hill. It is a large pit choked with debris and an adit was driven which entered it at 150 feet below surface. Little information was available as to what had been found but apparently nothing good. At *Hakkidonna*, which is on the slopes of the hill at a lower level, the old working is in the form of an irregular, steeply-inclined shaft or burrow which

has been proved to a depth of 300 feet. Adits were driven in and levels and drives opened up round the old working, to a depth of 300 feet, which failed to reveal any valuable body of ore. The shape of the working points to a pipe or narrow shoot of ore having been taken out. A large number of samples gave very poor results, the highest being 2·2 dwts., and there appears to be nothing to encourage further expenditure.

Bukkambudi.—A few miles north of Ajjampur on the hill overlooking the tank. There are considerable excavations with inclined and branching tunnels or burrows in a series of talc-chlorite schists veined with quartz and calcite. The workings originally attracted the attention of Mr. Mervyn Smith who applied for a mining lease but did not take it up or do any prospecting. He reported the presence of zinc and lead sulphides with some silver. The workings have been examined departmentally during the course of survey work and there seems to be little to justify expenditure on them. The irregular shape and branches appear to indicate that some branching shoots or impregnations were followed and taken out. The lead and zinc sulphides are in irregular bands or streaks in the rock and samples broken from the faces give less than one per cent of concentrates containing galena, blende and pyrites in a fine state of division. Small veins of quartz as well as the mineralized rock give small traces of gold and it is probable that the old workers removed some small shoots or richly impregnated and oxidised patches of ore carrying free gold. So far as can be seen the quantity of mineralized rock is small and the percentage of mixed concentrates insignificant.

SUMMARY.

An endeavour has been made to summarize as briefly as possible the present state of our knowledge about the occurrence of gold in Mysore and the prospects of further developments of mining work. It will be evident that the hopeful predictions of Bruce Foote and of many of the earlier prospectors have been seriously discounted by the large amount of

mining work which has been done at very considerable cost. These predictions were based on the successful results which were then being obtained beneath the old workings at Kolar, on the fact that many other old workings were known in other parts of the State but not tested, and on the fallacy—then so prevalent and not yet quite dead—that even though a mine or lode was comparatively poor at surface the odds were in favour of its increasing in richness at greater depths.

The work which has since been done by the Geological Survey and by various mining and prospecting parties has shown that the Kolar Gold Field possesses unique features in the number and size of the rich shoots situated on one or more well defined veins (which might properly be described as fissure veins) which are not repeated in other parts of the State where old workings occur. This would not prevent the opening up of individual mines if the shoots on which the old workings were sunk were found to continue in depth, and some may yet be found to do so. In the vast majority of cases however we have definitely shown that this is not the case and that many of the old workings are on what may be regarded as the mere stumps of shoots remaining after denudation of the upper parts. Many others, especially in the chloritic series, have been excavated on small rich lenses of limited extent and not connected with other lenses by well-defined veins which could be followed in the hopes of finding other lenses within reasonable distances. Other workings again are on veined or impregnated zones of schist the upper weathered portions of which—in which there may have been secondary concentration—were sufficiently rich in free gold while the unaltered portions below are too poor to pay.

The Kolar Gold Field is likely to continue a successful career for several decades and the area of ground mined may possibly be extended on the south and near the north of the Field. It is hoped that some further work will be done at Manighatta in view of the fact that a small shoot has been found, that this large body of schists is so similar in character

and disposition to the Kolar Field and that gold is prevalent in the soil and nullas of the area.

In other parts of the Province work will no doubt be resumed later at Jalagargundi and on the Honnali Field; and the prospects of opening up some large low grade bodies of schist or lode, susceptible of cheap mining and extraction, at such points as Honnehatti, Ajjanhalli and Kempinkote (Hassan) may yet attract the attention of capitalists who are prepared to spend considerable sums on speculative ventures.

Iron.

Iron Ores.

Iron ores are widely distributed in the State but very variable in character; and in comparatively few places are they found in sufficient abundance and purity to be worth attention for work on a commercial scale under modern conditions.

The following classification seems to be in accordance with the numerous observations so far recorded by the survey:—

(1) Banded ferruginous quartz rock which occurs as a common integral component of the Dharwar Schists.

(2) Desilicified portions of (1) with, in some cases, addition of iron from solution or by metasomatic replacement of quartz and silicates. These form rich hæmatite and limonite ores.

(3) Zones or layers of massive ore probably the result of the metasomatic replacement of silicates (igneous and metamorphic schists) by oxides of iron. These are either limonites or hæmatites and are sometimes associated with (1) and sometimes not. In some places they are associated with manganese ores.

(4) Magnetite and hæmatite lenses which appear to be of magmatic origin associated with ultra-basic rocks intrusive into the Dharwar Schists. They are usually highly titaniferous.

(5) Quartz magnetite ores which appear to be of magmatic origin and genetically related to the Charnockite series and therefore subsequent to the Dharwar Schists and to the fundamental gneiss. There are some runs of solid magnetite-hæmatite ore in the same neighbourhood which may belong to this series, but as connecting evidence is wanting we have not definitely classed them.

A note on these various types and their mode of occurrence will be found in Records Volume XIV, page 34, and the present notes will be confined to the more important localities which have been investigated and the quantities and character of the ores available. A number of analyses are given in Tables 5, 6 and 7 and will be referred to where necessary by their serial numbers.

ORES OF THE BABABUDAN HILLS.

The Bababudan Hills lie a few miles north of Chikmagalur in the Kadur District. They form a ring or horse-shoe-shaped chain of hills enclosing the Jagar valley with an opening at the west side where the Somavahini river flows out. The crest of the ring is formed nearly entirely of banded quartz iron ores (ferruginous-quartzites) dipping inwards at angles of about 45°. The iron ore in these rocks is largely hæmatite with some magnetite. In places, chiefly along the eastern crest for some miles north of Attigundi, the rock contains much more magnetite than hæmatite and bands of the former, up to 2 or 3 inches thick, alternate with finely granular quartz.

Magnetite Ores.

These more magnetic portions of the series yield from 35 to 50 per cent of magnetic concentrate, but the results which could be obtained in commercial concentrators and the grade of the concentrates have not been determined yet. Large quantities of such concentrates could be obtained but they would be two or three times as expensive as the hæmatite ores which will be described below and the expense would be justified only if the product was very high in iron and very low in impurities—especially in phosphorus and sulphur. This is a point to be determined by further investigation.

Hæmatite and Limonite.

On the eastern side of the chain the ores lie at surface in gentle undulations with some steeper folds and crumples. The lower layers are thick beds of the banded ferruginous

TABLE 5—*Analyses of surface samples of the Bababudan Iron Ores (dried at 100° C).*

Serial No.	Registered numbers	H_2O	SiO_2	Al_2O_3	Fe	Mn	S	P	TiO_2	Remarks
1	S_2/477	4·06	0·76	8·03	64·22	trace	0·034	0·048	...	From main scarp, Kemmangundi
2	S_8/29	...	1·75	4·67	61·08	...	0·029	0·043	...	
3	S_8/30	...	1·56	0·53	61·75	...	0·053	0·036	..	
4	S_8/31	...	1·70	5·34	59·18	...	trace	0·062	...	
5	S_2/479	8·34	3·63	6·56	55·11	0·80	0·502	0·044	...	Banded ore and ochre in road cutting.
6	S_8/26	...	3·23	10·04	48·08	...	0·087	0·242	1·05	Lateritoid ore on top of No. 5.
7	S_8/27	...	0·83	6·90	62·05	...	0·015	0·037	...	Central portions of Kemmangundi ore field.
8	S_8/28	...	1·01	0·10	65·33	...	0·023	0·069	...	
9	S_8/96	...	...	...	...	...	...	0·019	...	
10	S_8/97	...	...	...	...	...	...	0·041	...	
11	S_8/86	...	1·43	...	65·08	trace	trace	0·046	nil	Outcrops near Kemmangundi gorge.
12	S_8/87	...	2·40	...	62·27	0·184	0·088	0·049	trace	
13	S_8/88	...	0·88	...	64·55	0·089	0·089	0·045	trace	

(The dot in the table indicate that the element has not been determined).

quartzite which are overlaid by a series of banded iron ores and ochres with numerous layers, bands or lenses of hæmatite and limonite. Many of these harder bands, which may be several feet thick, outcrop in scarps or in long lines of disjointed blocks over an area of 30 square miles or so from Kemmangundi on the north to Attigundi on the south and between Kalhattigiri and Virupakshikan, east and west. The various ore fields or patches of ore are separated by intrusive diabases or diorites, which are often altered into ferruginous clays, or by patches of soil and jungle or ferruginous quartzites where the overlying series has been denuded away. A great many million tons of ore exist in this area but in widely separated patches, and transport from one point to another would be difficult owing to the roughness of the country and the numerous ravines and nullas. For practical purposes it would be necessary to select some particular ore field where sufficient ore could be obtained to run the proposed smelting plant for many years.

Residual Ores.

It is interesting to note that in some places the ferruginous-quartzites appear to pass upwards into laminated and porous hæmatite by the removal of the quartz in solution. This is well seen along the track about ¼ mile north-west of the bungalow on △5590 and at points round the north-west slopes of the Giri. A pit at the former point was sunk in this ore at a little higher level than the point at which the underlying banded quartzites are exposed in a nulla close by. An average sample of the pit is shown in analysis No. 14 and shows good ore with practically no silica. There is a large quantity of this material but it is friable and would probably produce too much fines for blast furnace work. The only point which raises some doubt as to its origin is the amount of alumina present (nearly 10 per cent). It is not known how much alumina the banded quartzites contain and the large amount of this constituent rather suggests that there may have been intercalated bands of trap in the original rock.

TABLE 6—*Analyses from trial pits, Bababudan Iron Ores (dried at 100° C).*

Serial No.	Registered numbers	H_2O	SiO_2	Al_2O_3	Fe	Mn	S	P	TiO_2	Remarks
14	S_2/498a	6·9	0·77	9·82	58·37	0·06	0·047	0·067	...	Pit ½ mile N.-W. of Kalhatti bungalow.
15	S_2/498c	9·94	1·50	6·99	55·89	0·10	0·048	0·105	...	Vesicular limonite } Pits on scarp overlooking Santaveri.
16	S_2/495	4·89	1·32	1·18	65·11	trace	0·027	0·069	...	Chiefly hæmatite } Pits on scarp overlooking Santaveri.
										Pits on Kemmangundi ore field.
17	S_3/80	...	0·80	...	61·49	trace	trace	0·112	Nil	Spongy surface crust, mostly limonite.
18	S_3/92	...	1·97	0·79	51·40	0·21	0·099	9·105	1·00	Spongy surface crust, mostly limonite.
19	S_3/82	...	0·61	...	64·25	0·120	0·021	0·052	trace	Harder hæmatite bands below crust.
20	S_3/84	...	1·43	...	57·72	0·15	0·061	0·063	trace	Harder hæmatite bands below crust.

TABLE 6—*Analyses from trial pits, Bababudan Iron Ores (dried at 100° C).—concld.*

Serial No.	Registered numbers	H_2O	SiO_2	Al_2O_3	Fe	Mn	S	P	TiO_2	Remarks
21	S_3/83	...	0·46	...	61·88	0·069	trace	0·099	0·96	Mixed small ore. Sorted out from pits.
22	S_3/93	...	1·07	8·80	56·50	0·20	0·044	0·086	0·73	
23	S_3/94	...	1·81	11·25	55·75	0·17	0·055	0·090	1·50	Thin banded ore.
24	S_3/76	...	3·71	...	63·73	0·134	Nil	0·069	trace	Softish red and black hæmatites (40 %).
25	S_3/90	..	9·56	0·62	42·40	0·30	0·059	0·122	0·70	Fines left after sorting out No. 24 (60 %).
26	S_3/77	...	3·89	...	54·95	0·11	0·022	0·061	trace	Lumps and pebbles in alluvium valley.
27	S_3/78	...	1·32	...	61·18	0·130	0·028	0·072	trace	
28	S_3/79	...	2·66	...	56·43	0·160	0·013	0·092	trace	
29	S_3/89	...	1·46	0·51	56·30	0·21	0·076	0·120	0·82	Samples of waste dumps from which the harder lump ore had been sorted out.
30	S_3/91	...	1·96	10·61	44·80	0·28	0·130	0·121	0·55	
31	S_3/95	...	1·44	2·25	55·25	0·03	0·047	0·120	0·80	

The more valuable bands of harder hæmatite and limonite occur in a banded series overlying the ferruginous quartzites and from the evidence obtained in a number of prospecting pits the series was probably originally composed of bands of mica-chlorite schists and chloritic and hornblendic trap. Their original character can only be surmised as they are now completely converted into banded iron ores and ochres with varying bands, etc., of harder hæmatites and limonites. The hardened bands give bold outcrops between which much of the surface presents an indurated crust, 2 to 5 feet thick, beneath which the more finely banded ore and ochre is comparatively soft. The original rocks appear to have been completely altered by removal of the silica, lime and magnesia, very little of which remain, and the concentration of the iron. The harder bands of hæmatite and limonite are probably those in which there has been considerable deposition of iron from solution over and above the general concentration effected by metasomatic replacement, and in some cases the hardened hæmatite has been observed to penetrate the banded ores and ochres in branching veins transverse to the banding.

Replacement Ores.

The harder crust, much of which is fairly good ore though often somewhat high in phosphorus, gives a deceptive impression of the amount of smelting ore available; for, on being broken through, it passes into soft banded ores and ochres of which probably 50 per cent would have to be rejected as too fine and soft. Such rejectable material is represented by the waste dumps from the pits at Kemmangundi (analyses 29, 30 and 31) which probably average from 50 to 55 per cent of iron and about 0·12 per cent phosphorus. Samples of the crust 4 to 8 feet thick are represented by analyses 14, 17 and 18 containing from 51 to 61 per cent of iron with about 0·1 per cent phosphorus and a good deal of combined water. Nos. 17 and 18 are mostly vesicular limonite and No. 14 chiefly hæmatite.

The Crust.

Lateritoid.

In low lying places especially where the crust has been denuded or much altered by water we get a highly vesicular or lateritoid (1) layer developed on top of the banded ores and even passing downwards between the harder bands, which are sometimes broken up into fragments by gradual subsidence and collapse. One such place is at the road cutting at the western end of the Kemmangundi field where a face of 10 feet of finely banded ore and ochre gave analysis 5 and the lateritoid layer over it, into which it appears to have altered, gave analysis 6. These are reproduced below for comparison showing the increase in alumina and the marked increase in phosphorus:—

	SiO_2	Al_2O_3	Fe	Mn	S	P	TiO_2
No. 5 ...	3·63	6·56	55·11	0·80	0·052	0·044	...
No. 6 ...	3·23	10·04	48·08	...	0·087	0·244	1·05

Earthy Hæmatites.

In one of the pits at Kemmangundi rather soft and earthy or stony looking red to black ore was met with for a depth of 9 feet. It is compact, non-banded and breaks with conchoidal fracture into lumps and small fragments and is suggestive of a completely altered band of trap. Of the material excavated 40 per cent was sorted out as lump ore 2 to 3 inches and over. This gave analysis No. 24 with nearly 64 per cent of iron and would form a valuable ore if it will stand transport. There is probably a large body of it. The remaining 60 per cent is inferior and contains much more silica and phosphorus but can be readily sorted out.

The harder lump Ore.

These are the best and most valuable portions of the series and include the outcrop blocks and the harder bands below surface. The analyses given show their character.

(1) 'Lateritoid' is a term suggested by Dr. Fermor to denote highly vesicular ferruginous material having somewhat the aspect of laterite though not sufficiently similar to typical laterite to permit of the latter term being employed or generally admitted. *Vide* "The Manganese Ores of India" by L. Leigh Fermor, D.SC., A.R.S.M., Memoirs of the Geological Survey of India, Volume XXXVII, p. 388.

TABLE 7—*Analyses of Iron Ores from various localities.*

Serial No.	Registered numbers	H_2O	SiO_2	Al_2O_3	Fe	Mn	S	P	TiO_2	Remarks
32	S_2/747	...	1·80	...	60·04	...	0·027	0·10	...	Limonites from Shankargudda associated with manganese ores.
33	..	...	2·76	...	52·30	8·5	...	0·089	...	
34	...	...	8·10	2·62	54·20	0·78	0·015	0·022	0·08	Limonite from Kumsi, combined water = 10·05 %.
35	J_4/117	1.23	0·88	1·79	56·82	0·38	0·049	Nil	11·60	Titaniferous ore from Ubrani contains 8·09% Cr_2O_3.
36	O/271	...	0·52	1·93	61·44	0·416	0·024	Nil	10·21	Titaniferous magnetite, Tagadur, contains 1·21% Cr_2O_3.
37	...	...	0·44	Nil	65·64	0·296	0·017	Nil	5·17	Magnetic concentrate from No. 6 – 81·31% of the whole.
38	...	...	0·84	9·65	44·64	0·89	0·052	Nil	30·37	Non-magnetic residue from No. 56 (calculated).
39	...	...	13·82	Nil	61·36	0·224	Nil	0·022	trace	Magnetic concentrate (45·56%) from quartz magnetite ore of the charnockite series (O/261).

The following remarks refer to the Kemmangundi area. Analyses 1 to 4 are from the main scarp over a length of 1,000 feet or so. 7 to 10 are from central outcrops and 11 to 13 are from a new deposit, a mile further north and close to the gorge leading through the outer escarpment of the Bababudans to the low country. All of these are outcrop samples and run from 61 to 65 per cent iron and about 0·02 to 0·05 per cent phosphorus. No. 19 represents bands of hard hæmatite at a depth of 13 feet but sufficient work has not been done to show how numerous these bands are or to what extent the heavier outcrops continue downwards.

In the valley in the middle of the deposit there is alluvial soil underneath which is a considerable thickness (14 feet in places) of pebbles and small boulders represented by analyses 26 to 28.

Quantity of Ore.

The foregoing account shows the very complex character of these deposits and without much further deep prospecting and sorting it is impossible to speak very definitely about quantities and grades. The following estimates refer only to the Kemmangundi field and must be regarded as tentative and are, we believe, conservative.

The area of the ferruginous deposits on the Kemmangundi field is almost 50 acres and the conditions noted as occurring beneath the surface crust may be expected to continue to depths of 50 feet and probably more.

If we take an average depth of 25 feet the total tonnage would be nearly 4,000,000 allowing 2 tons per cubic yard, and the average composition about the following :—

(*a*) Iron–57 per cent; Silica–2 per cent; S–0·05; P–0·08.

About 50 per cent would have to be rejected as too fine and soft for blast furnace work and the remaining 50 per cent would be rather better throughout than the above average.

This would give some 2,000,000 tons of usable ore out of which we might expect to get—

(*b*) 500,000 tons running 61 to 62 per cent iron and 0·05 per cent phosphorus.

(*c*) 1,500,000 tons running 56 to 57 per cent iron and 0·09 per cent phosphorus.

From the smaller deposit, about 30 acres in extent, near the gorge about 1 mile north of the former, we might expect at least half these quantities, but as this has not been prospected yet this is merely a general assumption.

However from these two deposits we might expect three quarters of a million tons with 0·05 per cent phosphorus and some two million tons with about 0·09 per cent of phosphorus or rather less.

These are only two deposits out of a large number in the whole area situated at distances of from 1 to 10 miles from this point over rough hilly country.

Cost of Ore.

Until more is known about the sub-surface distribution of the harder and better ore we cannot be very precise as to costs. They must be adversely affected by the roughness of the ground and by the fact that work will not be possible for more than five or six months in the year owing to the heavy monsoon conditions.

If we assume that excavation and sorting will cost on an average Rs. 2-8-0 to 3-0-0 per 100 cubic feet and that from this we get 1 ton of the better ore (*b*) this gives Rs. 2-8-0 to 3-0-0 per ton of ore.

If this grade only was required the surface outcrops would be taken and excavation confined to the heavier bands or zones in which we might expect some 3 tons per cubic foot. This would reduce the above charge to from As. 13 to Re. 1. If in addition, as is quite probable, an equal quantity of ore of class (*c*) was also required the charge would come down still lower. Adding supervision and royalty we might consider that the cost will probably be between 1 and 2 rupees per ton according to the grade demanded and for subsequent estimate we will assume the higher figure.

The ore will have to be taken down the steep Kemmangundi gorge, probably by a wire ropeway, and thence by a light railway to a smelting works at Benkipur or Shimoga for which a transport charge of Re. 1 per ton may be added making the cost Rs. 3 per ton at the works with possibilities of some reduction.

LIMONITE ORES IN THE SHIMOGA DISTRICT.

Some fairly extensive outcrops of limonitic ore have been found in the Shimoga District in the altered ferruginous schists and ochres which carry the manganese deposits.

Three analyses of these are given in Table 7 of which Nos. 32 and 33 are from Shankargudda and contain nearly 0·1 per cent phosphorus. No. 34 from Holmes' Block near Kumsi shows that in some cases these ores are fairly low in phosphorus (0·02 per cent) and further prospecting may disclose some valuable bodies of such ore which would be of great value with charcoal fuel for production of low phosphorus irons.

CHITALDRUG SCHISTS.

Considerable bodies of soft limonite ores with some bands of harder hæmatites occur in parts of the Chitaldrug schist belt especially towards the western side in the neighbourhood of Karekalgudda, Bodimaradi and Chiknayakanhalli. Many of them are too soft and friable for furnace work, but considerable spreads of surface boulders of the harder hæmatites occur in places. These ores are far away from the railway and from fuel or any possible smelting site and have not been closely examined at present. Their use would be justified only if they possessed special qualities not obtainable as easily elsewhere.

QUARTZ MAGNETITE ORES OF THE CHARNOCKITE SERIES.

These have been found south of Halagur in the Malvalli Taluk not far from the Cauvery Falls. A couple of runs or dyke-like veins of these extend for a couple of miles north and

south and are 10 to 15 feet thick. They are composed essentially of quartz and magnetite with subordinate amounts of hypersthene, amphibole, and garnet. They would require to be crushed and magnetically concentrated.

Tests with a hand magnet gave 45·56 per cent of concentrate containing 61·36 per cent of iron and 0·022 per cent phosphorus when crushed through 30 mesh; (Analysis 39). When crushed through 60 mesh the results were:—

Concentrate=54·95 per cent containing 66·37 per cent iron and 8·36 per cent insoluble residue.

It is not considered that these ores are of value at present. What the results of commercial concentration would be are not known, but the ferruginous silicates present will render it difficult to obtain a very clean product and the cost of the concentrated ore will be high—probably at least Rs. 7 to 8 per ton at the mines.

TITANIFEROUS IRON ORES.

A large number of outcrops have been found in the neighbourhood of Ubrani to the north of Tarikere and also in the Nuggihalli schist belt near Tagadur—south of Tiptur. They were investigated as possible sources of high class magnetites and hæmatites, but analyses showed the presence of much Titanium which renders them unsuitable for smelting work though they may possibly be of use in a small way for production of special titanium steels. Analyses 35 to 39 show the composition of these ores and of the magnetic concentrate and residue from those near Tagadur.

POSSIBILITIES OF UTILIZING THE ORES.

Indigenous Smelting Industry.

Iron smelting on a small scale has been carried on in most parts of the State in past times as witnessed by the numerous slag-heaps most of which mark the sites of abandoned works. A few furnaces still exist but are hardly ever used and the industry may be said to be extinct. The processes of work, which

have been described frequently, consisted in the smelting of selected ore with charcoal in small furnaces a few feet in height. A blast is obtained by means of skin bellows and the result is the accumulation of a more or less melted mass of iron and slag—which is called a "bloom"—in the hearth of the furnace. The bloom is withdrawn, reheated and hammered to weld it into a solid mass and to remove slag and cinder. It is cut up into convenient pieces of "wrought iron" from which implements are forged. When steel is required the wrought iron is cut into small pieces of ¾ lb. weight and each piece put in a crucible with some charcoal and bits of wood and leaf of the *Thangadi* plant which is supposed to possess special virtue for the process. The crucibles are sealed up with clay and heated in a charcoal hearth for 5 hours with the result that the iron absorbs carbon by a sort of cementation process and is converted into steel.

The steel produced is variable in character but often of high quality. The processes are wasteful and expensive compared with modern methods.

The operations have been examined and reported upon by various officers, but it is very difficult to arrive at any satisfactory estimate of costs.

The following statement gives the average consumption of materials as reported:—

	Wrought Iron tons	Iron Bloom tons	Iron ore tons
1 ton of steel requires	1·1 to 1·5	2 to 2·7	About 11·5
1 ton of wrought iron requires.	1	1·8	3·6 to 6·48
1 ton of iron bloom requires.	...	1	2 to 3·6

As regards the *charcoal*:—

To make 1 ton of bloom from ore requires 3 tons of charcoal.

" 1 ton of wrought iron from bloom requires 1·75 tons of charcoal.

" 1 ton of steel from wrought iron requires 3·25 tons of charcoal.

Therefore to produce 1 ton of wrought iron requires altogether 8 tons of charcoal,

and 1 ton of steel requires altogether 12 tons of charcoal.

As regards *costs* it may be noted that the ore is allowed to be taken free, charcoal is either free or a small seigniorage of about Rs. 3 per ton is charged and sometimes a yearly tax of from Rs. 5 to 12 per furnace was imposed. These very variable charges are *omitted* in the following estimates which are based simply on the labour required for collecting the materials and conducting the smelting operations: the wages quoted are very low, *viz.*, Rs. 40 to 50 per year per man, or considerably below present day rates. Under these conditions the averages of the various estimates which have been made come out as follows:—

Wrought iron.—	Calculated cost	Rs. 150 per ton
	Selling price	Rs. 260 do
Steel.—	Calculated cost	Rs. 490 per ton
	Selling price	Rs. 723 "

Apparently the work should be very profitable but the selling price is based on the reported value of small pieces sold locally and occasionally and cannot be considered as representing a fair or fixed market rate. The fact that all the furnaces have been moribund or closed down for some years past must, we think, be attributed to the fact that the material cannot be sold at a profit in competition with imported iron and steel which can now be easily obtained for less, not only than the selling prices given above but in most cases for less than the calculated costs of production. These

latter costs would be, we believe, materially increased if recalculated on present day rates of wages and the chances of resuscitating the industry on a profitable basis appear to be definitely removed even allowing the ore and charcoal to be taken free.

EXPORT OF ORE.

The prospects of exporting the ores from the Bababudans are not favourable at present. If we consider the deposits at Kemmangundi and others within a couple of miles, such as those along the scarp overlooking Santaveri and those around the south and west flanks of Kalhattigiri, we may expect to obtain several million tons of ore running 57 to 60 per cent of iron, 0·05 per cent phosphorus and 2 per cent or less of silica and the value of such ore would probably be Rs. 15 to 17 per ton in England. The phosphorus is the most important factor and the value of the ore would increase or decrease with this element.

If we assume that this ore can be put on the railway at Shimoga at Rs. 2 to 3 per ton and that it can be put on board ship at a port on the West Coast (Bhatkal for instance) for another Rs. 2 we may take the cost f.o.b. Bhatkal at about Rs. 5 per ton leaving from 10 to 12 rupees for freight to England. This is rather below what freights have been in the past and the ore would probably cost one or two rupees per ton more than it could be sold for. The English prices may increase from time to time and mining costs may be somewhat reduced and there is some possibility that both ends could be made to meet especially in the case of a company which required the ore for its own use and not for sale; but it is obvious that it will require favourable circumstances and careful management to effect even this. Some of the other ores in the Shimoga District may prove to be better placed and permit of a reduction of the mining and transport charges to the extent of one or two rupees per ton and it is likely that some suitable ore may be found along the Western Ghats along certain tracts on the west of the Shimoga District which

have not been examined yet and which would be much nearer to the port. Neither the port nor the railway exists at present and export is a question of the future and the above figures are given merely to indicate the principal factors so far as our present information goes.

SMELTING IN MODERN BLAST FURNACES.

The ores of Mysore are sufficiently abundant and of good enough quality to be suitable for the manufacture of pig iron on a considerable scale, but unfortunately the supply of fuel is either too limited or too costly to permit of this being undertaken except within certain narrow limits. The fuel required is either coke or charcoal and the position with regard to these will be explained very briefly.

Smelting with coke.—As there is no coal in Mysore it would be necessary to import either coal or coke and we may take it that coke will cost over Rs. 30 per ton and will be considerably more expensive than charcoal. The pig iron would probably cost about Rs. 55 per ton or about 2½ times as much as at the Tata Iron Works at Sakchi where coke can be obtained at some Rs. 7 per ton. The pig iron so produced would be similar to that made at Sakchi and it would be impossible to sell the Mysore iron in competition with either the Tata iron or imported iron except within a very limited distance from the works and the very small demand within such limited area, say a few hundred tons a year, is too small to make the work possible at a profit. Good imported iron is quoted at Rs. 60 to 65 at Indian ports and probably sells at Rs. 65 to 75. These prices could probably be reduced and the Tata pig iron could obviously be sold for considerably less, even in the south of India. It is obvious that Mysore pig iron costing some Rs. 55 at the works, nearly all of which would have to be sent to distant markets for sale, could not compete against these outside rivals.

It may be worth while however to note that the opening of a port on the coast west of Shimoga would reduce the cost

of coke and that this might reduce the cost of the pig iron to Rs. 45 or even less. Even then there would be little chance for the sale of any considerable quantity and the fact is merely noted for reference in connection with the preparation of steel which will be discussed later.

Smelting with charcoal.—This stands on a different footing from smelting with coke. Indian coke is fairly impure and contains 14 to 15 per cent of ash and the ash contains about 0·9 per cent of phosphorus practically all of which gets into the finished pig iron.

Charcoal on the other hand is free from both ash and phosphorus and the pig iron produced is usually of a higher grade than coke pig and sells at a higher price. Swedish charcoal pig costs about Rs. 75 f.o.b. Sweden, and would probably be worth Rs. 90 to 100 in Indian markets. At present very little is used in India but there is every reason to expect that a small output could be disposed of in India, Japan and Australia and that an industry could be developed in the manufacture of special castings for which charcoal pig is required —such as engine cylinders, chilled car wheels, rolls, etc. We may therefore consider the amount of charcoal pig which can be produced and its cost.

Charcoal.

The amount which can be produced is limited by the steady supply of charcoal which can be obtained from the forests without permanent depletion. The Conservator of forests has estimated recently that an annual supply of 20,000 tons of charcoal could be maintained from the forests of Kadur and Shimoga. In order to obtain this about 100,000 tons of suitable wood would have to be collected annually from forests spread over a large area and it would be necessary to provide 150 to 200 miles of light railways or tramways to collect the wood and bring the charcoal to a smelting work situated, let us say, at Shimoga. The Conservator estimates that the charcoal could be delivered at Rs. 25 per ton. We may accept these figures for a provisional estimate though we are inclined to regard them as

conservative and any increase in the supply or reduction in cost would tend to lower the cost of the smelted iron.

Smelting Plant.

With 20,000 tons of charcoal we can produce some 20,000 tons of pig iron and for this we might use three small furnaces of the Swedish type or one large furnace of the American type. The latter, if equally suitable in other respects, would be the more economical.

The furnace with its accessories in the shape of hot blast stoves, blowing engines, cranes, ladles and buildings would cost about 9 lakhs of rupees on which interest and depreciation at 10 per cent would come to Rs. 4·5 per ton on an output of 20,000 tons.

The costs of manufacture may be apportioned as follows, approximately :—

Cost of making Charcoal Iron.

Output 20,000 tons per annum.

1·65 tons of ore (Fe—60 per cent) at Rs. 3 per ton	...Rs,	4·95
1 ton charcoal at Rs. 25 per ton ...	... „	25·00
5 cwts. limestone at Rs. 5 per ton ...	... „	1·25
Lining and repairs to furnace ...	... „	1·50
Interest and depreciation (10 per cent) ...	... „	4·50
Supervision, labour and other charges ...	... „	8·00
Total cost per ton of pig iron	...Rs.	45·20

According to these figures we can make charcoal pig iron at about Rs. 45 per ton and it is probable that some of the items can be reduced in practice and that we might hope to get down to Rs. 40 or even a little less.

In the absence of an existing demand and reliable quotations for this class of material it is very difficult to say what the value of the product would be at the works, but it is probable that it would be worth from Rs. 55 to 70 per ton. At an average of Rs. 60 it might be regarded as sufficiently

attractive and there is a fair prospect that parts of the output made from specially selected ores and sold for special purposes would fetch considerably more.

The sale of pig iron is however only part of the scheme which contemplates the conversion of about half, or 10,000 tons, into steel. The remaining 10,000 tons would partly be sold as pig and partly made into castings for special purposes on which work an additional profit might be expected. As will be shown later, the steel-making portion may be expected to be feasible and profitable and without allowing for very special grades and special prices the work as a whole may be expected to yield a fair profit on the output of 20,000 tons with considerable prospects of increase from the development of special lines of work.

Before passing on to the question of steel-making we may very briefly consider the possibilities of smelting the ores electrically instead of depending entirely on our limited supplies of charcoal.

ELECTRIC SMELTING OF ORE.

Suggestions that electricity should be used for the smelting of iron ore and other metallurgical purposes are very popular in Mysore and a few words as to the comparative values of electricity and charcoal fuel may not be out of place.

The generation of electric power from waterfalls in Mysore is by no means very cheap. The water going over the falls is very variable and is reduced to comparatively small amounts during the dry months. Metallurgical industry requires, as a rule, a constant supply of power throughout the year and if a large amount is required it becomes necessary to provide large storage reservoirs for the excess water which runs to waste during the rains and this means added expense.

For the supply of power on a large scale the cost of generating the current is not likely to be less than 0·1 anna per unit (Kilo-watt-hour) and where the power has to be

transmitted to a smelting works at a considerable distance from the generating station the cost is not likely to be less than 0·2 anna per unit delivered at the works. Under certain favourable conditions a company might be able to obtain supplies from moderate distances (50 to 100 miles) at 0·15 anna, but it must be remembered that the maximum amount which has to be provided for is not used continuously throughout the year and for the purpose of making a comparison we will take the minimum cost for the power actually consumed at 0·2 anna per unit which is at the rate of Rs. 81 (£5-7-6) per Horse-Power Year.

In any specific case the actual rate quoted or estimated can be readily substituted for this figure.

In Norway and Sweden the work of recent years has shown that from 2,000 to 2,500 K.W. Hours are required to produce 1 ton of pig iron from iron ore. With the Mysore ores containing 60 per cent of iron it is probable that the figure would be about 2,500 K.W.H.

In addition about 7 cwts. of charcoal will be required to reduce the oxides of iron to metallic iron.

About 15 or 16 lbs. of carbon electrodes will be required per ton of iron and these will cost about 3 annas per lb. or Rs. 3 per ton of iron. Leaving out other charges we can now compare the relative costs of charcoal and electric energy :—

	Rs.
To produce 1 ton of pig iron by charcoal smelting requires 1 ton of charcoal costing	25

To do the same work electrically we require—

2,500 K.W. Hours at 0·2 anna ...	31·25
7 cwts. charcoal at Rs. 25 per ton...	8·75
16 lbs. of electrodes at 3 annas per lb.	3·00
Total	43·00

Electricity is obviously much more expensive than charcoal. In order to make the former equal the latter it would be necessary to reduce the charge for power by Rs. 18, (43—25) in which case 2,500 K.W. Hours would cost Rs. 13·25 which is at the rate of 0·085 anna per unit which is, we believe, considerably below the cost at which it is possible to generate it in Mysore.

At the rate of 0·2 anna per unit adopted above we may estimate the cost of smelting 1 ton of pig iron electrically as follows for an output of 20,000 tons per year:—

		Rs.
1·65 tons of ore at Rs. 3 per ton	...	4·95
7 cwts. charcoal ,, 25 ...	...	8·75
7 cwts. limestone ,, 5 ...	...	1·75
Electrodes 16 lbs. at 3 annas per lb.	...	3·00
Electric power 2,500 K.W.H. at 0·2 annas		31·25
Repairs and relining ...	...	2·00
Interest and depreciation ...	...	4·50
Supervision, labour and other charges	...	9·00
Total per ton of iron	Rs.	65·20

This is very much higher than the estimate of Rs. 45 for iron smelted in charcoal furnaces, and even with electric power at 0·1 anna per unit the cost would still be higher, *viz.*, Rs. 50 or thereabouts. The plant for this work would cost about 9 lakhs of rupees and include 3 furnaces of 3,500 horse-power each requiring about 7,000 horse-power to run.

Under existing conditions the electric smelting of the ores appears to be out of the question not only because it is more expensive than charcoal smelting but because the actual cost per ton (Rs. 65) appears to be too high to permit of the iron being sold at a profit.

STEEL-MAKING.

For the manufacture of steel we believe that it will be quite feasible to use electricity even though the latter may

cost more than 0·2 anna per unit and as a convenient figure on which to base estimates we will adopt a rate of 0·3 anna per unit equivalent to Rs. 123 (£8-4-0) per Horse Power Year.

Steel direct from Ore.

It is possible to make steel direct from the ore—that is without making pig iron first and this has been discussed in Bulletin No. 5. [1] On the assumptions then made, with power at rather less than 0·1 anna per unit it was argued that the cost of steel might come down to from 83 to 105 shillings per ton according to scale of output. With figures now available and making 10,000 tons per annum from 60 per cent ore with power (3,000 K.W.H.) at 0·2 anna the cost would be about Rs. 100 (133 shillings) per ton. The direct process is practically not in use and is not favourably regarded by most metallurgists and we can work cheaper by indirect methods.

Steel from Pig Iron

We have estimated that it costs Rs. 45 per ton to make the pig iron in charcoal furnaces. For the purpose of conversion to steel it would be perferable to make a *white* iron rather than ordinary foundry pig and this could probably be done somewhat more cheaply, say, at Rs. 40 per ton, and we shall adopt this figure.

The pig iron contains a little over 3 per cent of carbon and to make steel this has to be removed and the metal recarburized so as to contain from 0·06 to 1·5 per cent of carbon according to the character of the steel required. At the same time impurities such as phosphorus and sulphur are removed. In order to save the cost of remelting the pig iron it is advantageous to have the refining furnaces close to the blast furnaces so that the molten pig iron may be transferred from the latter to the former without being allowed to cool or solidify. The molten pig iron might be poured, from a ladle directly into the electric furnace and there refined by adding iron ore, which would oxidise or burn out the carbon, but such

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(1) Notes on the Electric Smelting of Iron and Steel by W. F. Smeeth, M.A. D, Sc., etc., Bulletin No. 5—Mysore Geol. Dept.

a process takes time and involves much consumption of electric energy.

A better scheme is to pour the molten pig iron into a mixer or converter and blow air through it, thereby getting rid of the carbon and effecting a partial refining. This partially refined metal is transferred to the electric furnace with the addition of fluxes and the refining completed. The metal can be brought to almost any desired degree of purity. The consumption of energy depends on the impurities present and on the degree of purity required and the figures given below are based on the average conditions which may be expected to obtain in the production of high-class carbon steels.

Without entering into the question of the type of furnace, we may take it that for an output of 10,000 tons of refined steel 2 furnaces of 5 tons capacity each will be required, one being held in reserve for the greater part of the time. The furnaces with their accessories will cost about Rs. 1,50,000, and the electric current can be generated at the works from the waste gases of the charcoal furnace.

The following figures are based on European practice :—

	Rs.
Cost of molten pig iron at Rs. 40 per ton ...	40·00
Cost of partial refining in converter ...	10·00
Oxidation loss	1·50
Electric power for refining, 200 K.W.H. at 0·3 anna per unit	4·70
Electrodes	1·25
Repairs and tools	2·00
Fluxes and ferro-additions	3·00
Interest and depreciation (10%)	1·50
Supervision and labour	3·00
Royalty, not included	...
Total per ton of steel ...	66·95

The molten steel will therefore cost about Rs. 67. If there is much refining to be done the cost for power will go up, but it is reasonable to assume that we should be able to make steel suitable for high-class forgings, castings and tools

at an average of from Rs. 67 to 75 or say for £4-10-0 to £5 per ton. The cost of converting the molten pig-iron to steel is therefore Rs. 30 to 35 per ton.

Steel from Scrap.

At the works, especially if casting, forging and machining is carried on, a good deal of scrap will be produced and this would provide additional work for the electric furnaces. In addition, it should be possible to purchase a certain amount of wrought iron and steel scrap from railways, workshops, etc. The amount obtainable is not very large and would depend on the price that could be paid. We believe that it should be possible to obtain some 2,000 tons a year at a cost of Rs. 30 per ton and that the cost of melting and refining this would be about Rs. 30 or less. This would give an additional output for the furnaces and every addition means decrease in standing charges.

Small Plant.

It may be noted that a small independent plant could be run on scrap for a production of about 2,000 tons a year using a 2½ ton furnace. The costs would of course be higher than if the work was combined with the larger iron and steel plant described above and there would not be room here for both. It is however an alternative in case the iron smelting scheme is not taken up. The cost of the steel would be in the neighbourhood of Rs. 70 to 75 per ton and the subsequent operations of casting, forging, etc., would all be more expensive on the smaller scale.

Value of Products.

It is a difficult matter to assess the value of the products from the steel works. Much depends on the grade of materials produced and on the development of markets. The materials would all be of comparatively high grades which are not being made in India at present, such as axle and tyre forgings, high-class steel castings, tool steel and steels for drills, jumpers, etc. Ordinary steels for rails, bars, sheets and rolled sections would be out of the question in comparison with similar materials made in India or imported. The market in India for the higher class

products is comparatively limited and we should probably have to seek outlets in the Straits, China, Japan and Australia.

The following figures are very tentative :—

Output of 2,000 tons per annum.—The products of the small scrap plant might be divided into 1,500 tons of forgings, castings, etc., valued at Rs. 180 per ton and 500 tons of tool and bar steel valued at Rs. 250 per ton.

With steel ingots costing Rs. 75 and allowing for expense of manufacture the former would cost about Rs. 140 and the latter about Rs. 170 per ton. We thus get the following estimate :—

1,500 tons forgings, etc., valued at Rs. 180 = Rs. 2,70,000.	Cost at Rs. 140 = Rs.	2,10,000
500 tons tool and bar steel valued at Rs. 250 = Rs. 1,25,000.	Cost at Rs. 170 = Rs.	85,000
	Balance Rs.	1,00,000
Rs. 3,95,000	Rs.	3,95,000

This balance would have to cover part of interest and depreciation, and management and should leave a very fair profit.

Output of 11,000 tons per annum.—For thé larger plant using steel converted from charcoal iron as well as scrap we might take the cost of the ingot steel at Rs. 70, cost of forgings, etc., at Rs. 120, cost of tool and bar steel at Rs. 150 and get the following :—

11,000 tons castings, forgings, etc., valued at Rs. 175 = Rs. 19,25,000.	Cost at Rs. 120 = Rs.	13,20,000
1,000 tons tools, bar, etc., valued at Rs. 200 = Rs. 2,00,000.	Cost at Rs. 150 = Rs.	1,50,000
	Balance = Rs.	6,55,000
Rs. 21,25,000	Rs.	21,25,000

The balance would have to cover interest, depreciation and management not already provided for and expenses of sale and a large proportion of it should be available for profit. The sale values depend on the quality of the products and the market demand for them and the figures adopted will be found, we believe, to err on the low side. There is little doubt about our being able to produce high quality and the only serious difficulty will be the finding of markets for the products at their proper values. High-class castings and forgings should be worth considerably more than Rs. 175 per ton and such items as tool steel, mining drills, jumpers, etc., should be worth Rs. 300 to 400 per ton. If markets are developed so that a considerable proportion of the output can be sold at the higher figures the profits would increase enormously and that is the prospect which we contemplate as eventually possible. On the other hand, there will be undoubted difficulty in securing these sales at first and much of the output may have to be got rid of at comparatively low prices in competition with poorer grades of material or to cover the expense of transport to distant markets and in view of this the average sale values have been estimated at fairly low prices. This is however largely conjectural and we cannot go into the matter more fully here; we have given our facts and assumptions and people with a knowledge of the business side can alter the items according to their knowledge and experience.

SUMMARY.

We have endeavoured to show that large quantities of good smelting ore are obtainable at a reasonable cost from the Bababudan Hills. There are some indications that better class ores, particularly in regard to lower contents of phosphorus, may be obtainable in parts of the Shimoga District. These have not been located yet in any considerable quantity, but the question is one of very great importance as the value of the ore and the profits to be derived from the finished

products would be increased very materially if the phosphorus could be kept low, say below 0·02 per cent. The resources of the forests would appear to permit of the smelting of some 20,000 tons of iron per annum of which half might be sold as charcoal pig iron or made into special castings and the other half converted to high grade steel in electric furnaces.

To establish an industry of this size some 50 lakhs of rupees would be required of which 20 lakhs would be required for the iron and steel works and 30 lakhs for the charcoal kilns and light forest railways for collecting fuel and bringing in charcoal and ore. The 20 lakhs or so for the light railways would not be needed all at once, but could be called up as extensions are required for tapping the various forests.

The establishment of such an industry would have far reaching consequences and would materially assist in development of local manufacturing and industrial work. The figures we have given encourage the view that the work would be profitable and if the finished products of really high grade can be maintained the profits should be materially increased. It cannot be too strongly insisted upon that the objects of the scheme should be to make and sell only high grade materials and that in view of the comparatively small scale of operations, the high price of fuel and the absence of a local market it would be quite impossible to compete in the ordinary grades of commercial iron and steel which are now being made in India or imported.

The establishment of a new industry in a new place and under untried conditions always involves many doubtful and difficult problems, and while recognizing this clearly we are still of opinion that a successful and profitable industry can be developed on the lines indicated provided that thoroughly experienced supervision and business capacity is provided and that the sympathetic co-operation of Government is secured for the regular supply of charcoal and other facilities.

Manganese.

MANGANESE ORES.

Distribution.

The manganese ores appear to be confined to the Chloritic or Upper Division of the Dharwar Schists. None has been found in the Hornblendic Division. The ores are found in the Shimoga, Kadur, Chitaldrug and Tumkur Districts and their distribution is shown on the map by square dots. The dots represent deposits or groups of deposits where appreciable quantities of ore have been found, even though it may not have been found possible to work them commercially owing to the grade being too poor. In Table 8 a list is given of the principal deposits or localities where ore has been mined and the quantities exported to the end of 1914. In several cases no exports have been made, but ore has been mined and stacked which is either too poor to export or is awaiting more favourable market rates.

From the map it will be seen that most of the deposits are confined to two divisions, *viz.*—

(1) the *Shimoga Division* in which the deposits are situated in the schists surrounding the large mass of the Shimoga gneissic granite; and

(2) the *Chitaldrug Division* in which the deposits lie near the western edge of the Chitaldrug schist belt in the Chitaldrug and Tumkur Districts.

In addition, some isolated deposits have been found near Hoskere and Halekal from which small quantities of ore have been obtained.

In the Shimoga Division some of the most important deposits are situated along the crest of Shankargudda ridge from 1½ to 3 miles south of the △3393. For some years

after their discovery by Mr. Slater the results obtained were poor. Deeper work during the past two or three years has shown that the deposits are fairly large and there are indications that several hundred thousand tons of marketable ore will be obtainable. The character of the ores is shown by the analyses in Table 11.

Further south along the ridge at Adgadde and Hemmaki (near Mandagadde) small deposits of ferruginous ores have been found.

In the large area of schists to the west of the Shankargudda ridge low grade ores have been found near Aranelli, Karkodlu and Puradkoppa most of which are high in iron and phosphorus. This area is worth further prospecting, but the heavy jungle and soil will render the location of deposits a matter of considerable difficulty and expense.

Passing northwards a small amount of ore has been obtained near Choradi and some very ferruginous ores mixed with limonites at Tuppur, about 5 miles west of Choradi.

To the north of Kumsi the schists swing round eastwards and the important deposits at Holmes' pit and Python lie about 4 miles N.N.E. of Kumsi. Over 200,000 tons of ore have been exported from Holmes' pit and there is still a large quantity to be obtained though the ore bodies appear to be petering out at a depth of 80 feet from surface.

The Python pits lie about a mile east of Holmes' pit and are expected to yield a fair quantity of 1st and 2nd grade ore. It is probable that other deposits will be found in this neighbourhood, but soil and jungle render their location difficult. The deposits at Holmes' pit and Python were searched for and prospected for several years before the ore bodies were located. A little to the east of Python the schists swing north again and we come to a series of small deposits lying round the north of the Saulonga granite in the Shikarpur Taluk. These are situated in groups near the villages of Markande, Ittigehalli, Hosur and Ballur and some ore has been reported from the neighbourhood of Kaginelli.

TABLE 8.—*Localities of the principal deposits of Manganese Ore.*

Taluk	Locality	No. of license or lease	Holder of current license or lease and number	Quantity exported Tons
	SHIMOGA DISTRICT.			
Shikarpur ...	Ittigehalli	P. L. 93 ...		} 3,003
	Hosur and Ballur	,, 99 ...		
	Kaginelli, N. of Ballur	,, 110 ...		
Kumsi (Sub-Taluk)	Holmes' block, Kumsi (includes Holmes' pit, Python and Sigimatti).	M. L. 142 ...	The Workington Iron and Steel Co., Ld., M. L. No. 142.	208,436
Channagiri ...	Hoshalli near Joladhal	P. L 116 ...		29,905
	Hoskere	,, 210 ...		
Shimoga ...	Shankargudda	M. L. 141 ...	The Workington Iron and Steel Co., Ld., M. L. No. 141.	14,480
	Bikonhalli and Kunchanalli	P. L. 27 ...		3,297
	Bhadigund	,, 265 and 290		1,638
	Balekatte near Shiddarhalli	,, 153 ...	Messrs. Jambon & Co., P. L. No. 153.	
	Hill 1½ miles N.W. of Shiddarhalli	,, 102 and 372	Mr. S. N. Subba Rao, P. L. No. 372.	
	Mavinkere E. of Masarahalli	,, 215 ...		70
Tirthahalli ..	Aranelli (Siddargudda and Chaudigudda slopes) ...	,, 86 ...		753
	Karkodlu 10 miles W.S.W. of Shankargudda ...	,, 118 ...		
			Total ...	261,582
	KADUR DISTRICT.			
Tarikere ...	Shiddarhalli 8 miles N. of Tarikere	P. L. 96 and 186 ...		10,285
			Total ...	10,285

	CHITALDRUG DISTRICT.			
Davangere ...	1½ miles S.W. of Halekal	P. L. 100 ...		10,510
Holalkere ...	Davanhalli and Kandavadi ... } E. of Jajur Railway Station.	" 312 ...		911
	Chikkandavadi ...	" 60 ...		25
	Sadarhalli ...	" 108 and 376		759
	Arasangatta ...	" 59 ...		800
	Mahadevapur ...	" 417 ...	Mr. V. Manickavelu Mudaliar, P. L. No. 417.	
	△ 2706 2 miles N.W. of Shivagange	" 104 and 376		248
	Shivagange	" 366 ...		10
Hosdurga ...	Karekalgudda, 6 miles N. W. of Madadkere ...	" 43 and 411...	The Peninsular Minerals Co. of Mysore, Ld., P. L. No. 411.	22
	Kenkere, 3 miles N. W. of Madadkere	" 43 and 412...	Do P. L. No. 412	
	Madadkere	" 41 ...		
	Hills 3 miles S. of Chik Byalkere	" 31 ...		11
			Total ...	19,789
	TUMKUR DISTRICT.			
Chiknayakanhalli...	Hills 1 mile S.W. of Janehar N.E. of (.. ...	P. L. 53 ...		7,011
	Hills 2 mile N.E. of (... ...	" 51 ...		668
	Hill 1 mile W.N.W.	" 55 and 413...	The Peninsular Minerals Co. of Mysore, Ld., P. L. No. 413.	14,891
Tiptur ...	Karakurchi, W.N.W. of Dodguni	" 55 and 414 ..	Do P. L. No. 414	
Gubbi ...	3 miles N.N.E. of Dodguni	" 33 and 410...	Do P. L. No. 410	
			Total ...	22,285
			Grand Total to end of [redacted] ...	306,841

Coming south again we find a deposit at Bikonhalli, 5 miles north of Shimoga, from which some 3,000 tons were obtained of cavernous and somewhat siliceous ore capping a small hill which is now exhausted.

It may be noted that the better class ores such as those at Shankargudda, Choradi, Kumsi and Bikonhalli lie on an inner chain not far from the boundary of the Shimoga gneissic granite, while the outer chain embracing Karkodlu, Tuppur and the Shikarpur group contains, as a rule, low grade deposits high in iron and usually particularly high in phosphorus.

The other deposits of this division lie to the east of the Shimoga granite in the Channagiri and Tarikere Taluks. Amongst these may be mentioned a number of small deposits to the south of Joladhal, of which that at Hoshalli was the most important but is now abandoned. Here the ore went down nearly vertically in a banded or impregnated zone some 6 feet or so in width. At a depth of 40 feet the band was rather split up and not sufficiently wide or solid to justify the cutting back of the narrow excavation or the adoption of underground mining.

The other places marked on the map are :—

Bhadigund, 7 miles south of Joladhal.

Shiddarhalli and Balekatte, 8 miles north of Tarikere.

Mavinkere, 4 miles east of Masarhalli Railway Station.

The various pits at Shiddarhalli yielded over 10,000 tons of 2nd grade ore in which the silica was rather high and a good deal of sorting was required. Much of the ore was float in lateritic soil and clay some of which was pisolitic. Beneath the float were some bouldery ore bands dipping about 30° to 40° to the north which were followed to a depth of about 30 feet but were not sufficiently large to justify the large amount of excavation necessary to carry down the open workings. The area contains a good deal of manganese most of which is 2nd or 3rd grade ore and is contained in talus or float deposits; it is possible that deeper deposits of good ore exist which

are covered by the heavy overburden of soil and talus and the search for which would be expensive and largely fortuitous.

In the Chitaldrug Division manganese has been found at many points along the western sides of the Chitaldrug schist belt, but the ores are mostly poor and highly ferruginous.

A considerable group of deposits occur to the east of Jajur consisting largely of low grade talus material. On the ridges a few miles to the south there are indications of vertical bands of psilomelane in the schists, but not sufficiently strong to warrant either open work or underground mining. It is however an area which might well receive some further attention. Some ore has been excavated at Karekalgudda and Kenkere, to the north-west of Madadkere, and recent work has shown that some fair quantity of fairly good ore may be obtainable with careful work and close attention to sorting. Much of the ore is mixed with limonite.

Other small deposits have been found at Chik Byalkere and to the east of Chiknayakanhalli.

A small quantity of ore was obtained at Narsihalli, Karakurchi and Dodguni and recent prospecting work suggests that considerable quantities still await development, some of which will be of fairly good grade, and work is now being proceeded with by the Peninsular Minerals Company.

The ores of this area are associated with iron ores and large quantities of low grade ferruginous ores appear to exist and it is possible that deeper prospecting will disclose further quantities of higher grade ore. Most of the high grade ore at present developed in said to be pyrolusite.

Output.

The following table gives the total quantity of ore exported from the various Districts from 1906 to the end of 1914.

TABLE 9—*Quantity of ore exported from 1906-14.*

Year	Export Tons					Royalty
	Shimoga	Chitaldrug	Tumkur	Kadur	Total	
						Rs.
1906 ...	36,534	11	4,117	...	40,662	15,743
1907 ..	53,241	920	10,866	4,698	69,725	26,550
1908 ...	47,038	1,212	4,172	2,148	54,570	20,464
1909 ...	16,135	9,607	...	3,389	29,131	8,784
1910 ...	28,349	1,029	...	...	29,378	18,052
1911 ...	13,081	...	1,862	...	14,943	5,604
1912 ...	24,085	...	702	...	24,787	10,286
1913 ...	23,742	10	566	...	24,318	9,851
1914 ...	19,377	...	...	...	19,377	4,817
Total ...	261,532	12,789	22,285	10,235	306,841	1,20,151

Geological occurrence.

We cannot devote much space to this intricate and often obscure problem. Those who desire further information may be referred to Dr. Fermor's valuable Memoir on the "Manganese Ore Deposits of India" (1) and to the summary of his views in the "Quinquennial Review of the Mineral Production of India" (2).

In Mysore the deposits appear to be confined to the chloritic series of the Dharwar schists and to have resulted from the alteration of these schists to a comparatively small depth from surface. The manganese probably occurred originally in certain of those schists in minute quantities in the form of manganese, bearing silicates. The various silicates of the schists were subsequently broken up by the action of circulating waters and solutions giving rise to solutions containing manganese, iron, etc., from which the oxides of manganese and iron were deposited in segregated patches,

(1) Memoirs of the Geological Survey of India, Vol. XXXVII.
(2) Records of the Geological Survey of India, Vol. XLVI.

lenses, bands or veins in sufficiently concentrated masses to form ores. In these segregated patches the original schist has been removed and replaced by the manganese and iron minerals to a variable extent and we get various earthy ores, wads, etc., hardening up in places by addition of further mineral matter to rich ores. Local conditions, of which we have no knowledge, have determined that in places the manganese is deposited by itself forming manganese ore and in other places the iron segregates to itself forming iron ore, while between these types there has been a very extensive formation of mixed ores in which the relative proportions of manganese and iron vary widely. It is not possible to say how deep the original solvent action may have extended, but it is probable that the concentration and formation of these ore masses is confined to comparatively shallow depths probably within 100 to 200 feet from surface and it is doubtful if any of the Mysore deposits will exceed 100 feet or so in depth. At Kumsi ore is now being worked at over 80 feet below surface and there are signs that the ore bodies are changing and petering out.

The ores are frequently associated with banded ferruginous quartzites and it has been suggested that the alteration of these rocks may have given rise to the ores. It is true that these rocks are sometimes veined and impregnated with manganese and that much altered remnants of them are found in the banded ochres and altered schists in which the manganese ores occur. As one of the members of the schist series they may have contributed their quota to the manganiferous solutions, but the proportion was probably not large compared with that from the large masses of altered schist with which they are associated.

The larger deposits in Mysore occur on ridges or comparatively high ground and the presence of the highly resisting quartzites has in many cases determined these elevations and preserved the ores and the soft ochres from denudation and the relationship of the quartzites to the ores may be protective rather than genetic.

A number of the smaller deposits occur on the slopes and on the lower ground and these appear to be largely of the nature of detrital or talus deposits derived from the breaking down of ores once situated at a higher level. Ores have been found *in situ* beneath some of these talus deposits, but they have not been proved to be extensive and may represent the remnants or roots of larger lenses or bands the greater portions of which have been worn away.

Laterite.

Lateritic material is frequently associated with the ores. In some cases, as at Shankargudda, this appears to be genuine laterite formed *in situ* on the surface of the altered schists. On parts of the ridge thin ore bands alternate with ochre and altered schist and the laterite has eaten its way down between the ore bands. Fragments and lumps of ore remain in the laterite and while these have been to some extent dissolved it is probable that some of them have, at some period, formed centres or nuclei for the segregative deposition of further quantities of manganese. The breaking up and denudation of these lateritic masses (or *lateritoid* as Fermor calls them) and of exposed ochres and ore bands have given rise to numerous talus deposits on the slopes or lower ground in which large lumps and nodules of ore are irregularly distributed in ferruginous clay and gravel which is often reconsolidated into lateritic material of secondary origin. These talus deposits and the soil associated with them are often very full of gravel consisting of rounded and concentric pisolites of limonite with variable amounts of manganese. Some of these are derived from the weathering of pisolitic ore and some correspond to the ordinary lateritic gravel which is so commonly found as detrital material derived from typical laterite. In the latter case the pisolites do not exist in the laterite itself, but are produced by the breaking up and rounding of small veins or segregations of limonite with subsequent coats of limonitic ore deposited round them.

At Holmes' pit, Kumsi, there are large masses of low grade pisolitic manganese ore, fractured into lumps, between which

the ore has altered to highly ferruginous material which is becoming cavernous and lateritic in appearance.

Grade and Composition of Ores.

In Table 11 is given a selected list of analyses which have been kindly furnished by the licensees of the various blocks. The list is less complete than could be desired, as in many cases shipments have been made of mixed ores from several blocks and complete analyses are not available for many of the separate deposits. When considered in bulk the ores are considerably lower in manganese than those from the Central Provinces. The greater portion consists of psilomelane the lower grades of which are frequently pisolitic. There is a fair amount of wad passing into psilomelane, some pyrolusite much of which is cavernous, rather friable and powdery, and some manganite and other undetermined varieties.

The grading of the ore is an arbitrary matter and the following table shows the approximate limits adopted in the Central Provinces and in Mysore.

TABLE 10—*Grading of Manganese Ores.*

	Central Provinces	Mysore
1st grade ...	50 per cent Mn.	47-52 per cent Mn.
2nd „ ...	48-50 „ ...	42-47 „
3rd „ ...	45-48 „ ...	38-42 „

According to this the Mysore ores are relatively about one grade lower than those of the Central Provinces in manganese contents and many of the former would be classed by Fermor as Ferruginous Manganese Ore or Manganiferous Iron Ore.

On the other hand, the low silica and phosphorus in the Mysore ores and their good smelting qualities raise their value

and justify the better class ore being regarded as 1st grade even though it may average only about 48 per cent Mn.

From Table 11 it will be seen that in addition to much local variation there are some general variations in the ores from different localities. The ores from round about Joladhal in the Channagiri Taluk and Shiddarhalli in the adjoining Tarikere Taluk are remarkably low in phosphorus often under 0·01 per cent. Much of this ore is low in manganese and high in iron and some fairly high in Silica. At Holmes' pit, Kumsi Taluk, the phosphorus is low, averaging about 0·04 per cent, and is still lower in the Python deposits close by.

At Shankargudda both phosphorus and iron are higher than at Kumsi and average about 0·07 per cent and 10 to 12 per cent respectively. The ores at Karekalgudda and Kenkere in the Hosdurga Taluk appear to be somewhat of the same class. At Karkodlu and other small deposits in the Tirthahalli Taluk and in the small deposits around Itigehalli, Hosur and Ballur in the Shikarpur Taluk the phosphorus is much higher than elsewhere and runs from about 0·1 to 0·25 per cent and the iron and silica is also high.

Table 11—*Analyses of Mysore Manganese Ore.*

No.	Place	License No.	Mn	Fe	P	SiO_2	Al_2O_3	Description
				SHIMOGA DISTRICT.				
1	Holme's Pit, Kumsi ...	M. L. 142 ...	25·67	27·24	0·031	2·81	6·5 approx.	Low grade; pisolitic; becoming lateritic.
2	Do do ...	,, ..	35·42	14·31	0·049	5·50		Pisolitic float ore in lateritic debris N.E. of pit
3	Do do ...	,, ..	36·40	15·6	0·037	2·5	6·98 ...	Average of 3rd grade, chiefly psilomelane.
4	Do do ...	,, ...	40·20	6·0	0·018	4·23	17·05 ...	Aluminous ore N.E. corner of pit.
5	Do do ...	,, ...	54·5	5·98	0·042	1·5	Probably under 2 per cent.	Psilomelane, main run of boulders.
6	Do do ...	,, ...	42·4	10·6	0·062	2·2		Black wadlike ore hardening into psilomelane.
7	Do do ...	,, ..	53·0	5·5	0·045	1·02		wad.
8	Do do	,, ...	48·0	7·5	0·04	1·5		ore.
9	Python No. 1, Kumsi...	,, ...	33·7	15·2	0·02	5·5	5·5 ...	
10	Do do ...	,, ...	37·9	11·8	0·02	5·5	5·5 ..	
11	Do do ...	,, ...	42·6	9·0	0·027	6·01	8·86 ..	ne.
12	Do No. 2 do ...	,, ...	36·8	18·5	...	...		Pisolitic float.
13	Do do ...	,, ...	46·0	9·8	0·038	3·7		Top 6 feet below float.
14	Do do ...	,, ...	50·5	...	...	...		Silvery psilomelane.
15	Ridge deposit, Shankargudda.	,, 141 ...	44·8	13·0	0·068	2·0		Psilomelane. To depth of 5 feet in lateritoid.
16	Do do ...	,, ...	46·81	10·0	0.084	2·0		Banded ores underlying No. 15, from 5 to 16 feet.
17	Knoll deposit ...	,, ..	51·10	5·10	0·047	1·35		Average.
18	Original workings ...	,, ...	32·34	22·38	0·092	3·89		Pisolitic; surface ores.
19	Do do ...	,, ...	40·04	15·87	0·127	2·96		Pisolitic; various stacks.
20	Do do ...	,, ...	48·50	13·0	0·063	2·0		Average 2nd grade. Psilomelane underlying pisolitic.
21	Do do ...	,, ...	49·28	10·70	0·061	0·89		Sorted ore.
22	Do do ...	,, ...	51·48	8·90	0·105	0·70		Do
23	Do do ...	,, ..	47·5	12·10	0·074	1·06		Average of 1st grade.

TABLE 11—*Analyses of Mysore Manganese Ore*—concld.

No.	Place	License No.	Mn	Fe	P	Insoluble residue	Al_2O_3	Description
				SHIMOGA DISTRICT.				
24	Karkodlu; Tirthahalli	P. L. 116 ...	33·21	23·92	0·155	7·05		Talus deposits N.E. of hill.
25	Itegehalli; Shikarpur...	„ 93 ...	48·16	13·54	0·256	6·0		Very small quantity.
26	Ballur; do	„ 99 ...	32·52	12·38	0·120	28·70		Lateritoid ore; dressing makes little improvement.
27	Buda matti peak; Joldhal.	P. L. 116 ...	49·56	7·29	0·081	1·2		sfly pyro- r cent.
28	Buda matti east; Hoshalli.	„ ..	39·62	12·08	0·009	4·4		Talus deposit of limonitic psilomelane.
29	Hoshalli-Joldhal ...	„ ...	46·0	...	...	...		Average of sorted ore. Largely pyrolusite and manganite. Some of the ore is said to have given over 50 per cent.
30	Treasury Hill; 2 miles S.S.E. of Hoshalli.	„ ...	23·4	28·46	0·001	6·55		Banded psilomelane and limonite.
				KADUR DISTRICT.				
31	Shiddarhalli; Tarikere	P. L's. Nos. 96 and 136.	[illegible]·7	8·50	0·003	8·0		Average of several pits. Some ore running 48 49 per cent Mn and 2·5 per cent insoluble residue also obtained.
				CHITALDRUG DISTRICT.				
32	Sadarhalli, Chikjajur ..	P. L's. Nos 108, 312 and 375.	37·7	21·3	0·018	2·1		Sorted ore at station.
	Do do ...	„ ...	19·0 to 26·0	38·0 to 27·0	...	...		Samples from various pits.
33	Karekalguda ...	P. L's. Nos. 48 and 141.	47·60	10·0	0·065	1·68		The average ore shipped ran about 45·5 per cent. There is a lot of low grade ore under 40 per cent.
	Do ...	„ ...	41·20	17·0	0·068	2·13		
34	Kenkere ...	P. L's. Nos. 48 and 412.	50·72	7·35	0·06	1·85		

The workings at Kumsi and Shankargudda have shown that a notable improvement in grade occurs at several points at a small depth below surface below the 3rd grade ores, many of which are pisolitic. Analyses 9 to 11, 12 to 14, 15 and 16, 19 and 20 show this improvement and we have been informed recently that the ore in some of the laterite which averaged about 30 per cent manganese has now been succeeded at a depth of 25 or more feet by ore running 45 to 46 per cent manganese. It is interesting to note also that much of the float ore in lateritic soil and gravel is of comparatively low grade and that beneath it ores of better grade have been found. This is particularly the case when the float is composed of pisolitic ore and it seems to be the rule that the pisolitic ores when *in situ* are restricted to the more superficial portions of the deposits. The origin and relationships of these pisolitic ores are still very obscure, but from the point of view of practical prospecting it is important to find that low grade float and surface ores are sometimes underlain by higher grade ores and that surface trenches to a depth of 10 feet or more may reveal only poor ores and cause abandonment of work leaving better ores below undetected and untouched.

Improvement in Depth.

The cost of winning the ore and taking it to a market is a very variable one and depends on the character of the deposit, distance from a railway and freight charges. The following figures for the Central Provinces are given by Fermor. (1)

Cost of Ore.

Contractors are paid from Rs. 30 to Rs. 60 per 1,000 cubic feet of stacked clean ore. At 16½ cubic feet to the ton this comes to eight annas to one rupee per ton of ore. An additional payment of Rs. 5 to Rs. 6 per 1,000 cubic feet of excavation is made to cover the cost of removing waste material the proportion of which to ore varies very considerably. This charge may amount to from one anna to one

(1) Memoirs of the Geological Survey of India, Vol. XXXVII, Chapter XXIII.

rupee per ton of ore making the contract charge 9 annas to Rs. 2 per ton. Dead work, plant, tools and administration may vary from 8 annas to Rs. 1-8-0. Transport to railway by cart costs 2¼ to 2¾ annas per ton mile and loading into railway waggons 1 to 1½ annas. Various wharf dues at Bombay vary from 11½ annas to Rs. 1-8-0 and at Marmugoa Rs. 1-3-0.

Ocean freights including insurance have varied from Rs. 12 to 15 and charges at destination run from 14 annas to Rs. 1-11-0.

These charges are assembled in Table 12 to give an idea of average cost of ore c.i.f., English and Continental ports.

In Mysore we have comparatively few figures relating to large consignments of ore. Those despatched by the Workington Iron and Steel Company go mainly to their own works in England while much of the ore obtained by other licensees has been sold at contract prices on the railway or at Marmugoa.

At Kumsi and Shankargudda in the Shimoga District, where the most extensive workings are situated, the average contract rate is about Rs. 2-2-0 per 100 cubic feet of excavation excluding preparation of site, removal of surface soil, etc. The cost per ton depends on the relative amount of ore and waste or *mutti*. Except in the case of talus deposits the ore bands and lenses are usually steeply inclined and in order that a fair proportion of ore may be obtained it is necessary that the ore bodies should be wide or that several bands should be sufficiently adjacent to be included in one pit. At Kumsi the heavier ore bands yield about 3 tons per 100 cubic feet and the average is about 1½ tons of marketable ore, *i.e.*, excluding large quantities of low grade ferruginous ore. At Shankargudda the quantities are rather higher, say 3½ and 2 tons, respectively. The average contract rate at Kumsi is therefore about Rs. 1-6-0 per ton and includes mining, sorting and removal of waste.

Supervision, tools, plant aud loading costs Re. 1 to Rs. 1-2-0.

Transport on tramway (27 miles) to Shimoga including maintenance, running costs, loading and unloading, Rs. 2-3-0.

Administration, office, royalty, etc., Rs. 1-6-0.

Rail to Marmugoa and port charges, Rs. 6-8-0.

Sea freight and insurance, Rs. 12-12-0.

The figures for the Central Provinces and Mysore may be put in the following tabular form:—

TABLE 12—*Cost of Manganese Ore per ton.*

	Central Provinces *via* Bombay							Shimoga (Mysore) *via* Marmugoa	
	Limits					Average			
	Rs.	a.		Rs.	a.	Rs.	a.	Rs.	a.
Mining work								1	6
Supervision, tools, etc.	1	0	to	4	0	2	12	1	1
General administration								1	6
Transport to railway	Nil		to	5	0	1	8	2	3
Railway freight	7	6	to	8	15	8	0	6	8
Handling at port	0	10½	to	1	8	1	4		
Agents' commission	Nil		to	0	4	0	2	0	2
Cost f.o.b. at port	9	0½	to	19	11	13	10	12	10
Sea freight and insurance	9	0	to	15	0	12	0	12	12
Destination charges	0	14	to	2	0	1	4	1	4
Cost c.i.f. at destination	21	8	to	36	11	26	14	26	10

The ore from Kumsi therefore costs about Rs. 6 per ton at Shimoga excluding interest on the cost of the tramway which may raise it to Rs. 7 per ton. Such charges as interest, administration and tramming depend largely on quantity and due allowance must be made for this. In cases where bullock carts have to be used the usual rate is four annas per ton mile and the cost of ore from such properties as Shiddarhalli and Hoshalli, situated up to 15 miles from the railway at Tarikere or Benkipur, used to come to some Rs. 8 or 9 at the railway

station. We may take it that ore from the various manganiferous areas in Mysore will usually cost between 12 and 15 rupees per ton f.o.b. Marmugoa and the question whether it can be sold at a profit or not depends mainly on the market rate and on sea freights.

Value of Ore.

Manganese ores are sold on a basis of so many pence or annas *per unit* of manganese contained in the ore—the number of units being equal to the percentage of manganese.

The sale value of a ton of manganese ore containing 48 per cent of Mn. when the market rate is 10 annas per unit is $48 \times 10 = 480$ annas, or Rs. 30. The market rate varies for 1st, 2nd and 3rd grade ores and there are certain restrictions if the silica exceeds 10 per cent or the phosphorus 0·1 per cent.

The market rates have varied very considerably during the past few years.

In 1906-07 the rate for 1st grade ore rose to between 15 and 16 annas per unit and there was a considerable boom in mining and prospecting for manganese.

In 1908-09 the rate fell to about 9 annas and work became much restricted as many of the ores could not be exported at a profit.

In 1913 it rose to between 11 and 12 annas but these better prices were discounted by high shipping freights. There was a fall again in 1914 and since then war freights have rendered shipments almost impossible.

As already pointed out much of the Mysore ore is 2nd or 3rd grade and the rates for these run about one anna per unit less for each successive grade. If 1st grade is 9 annas, 2nd grade will be about 8 and 3rd grade about 7 annas per unit. Assuming according to Table 12 that the Mysore ore can be delivered in England or Europe at a cost of Rs. 27 per ton or 432 annas—

a 48 per cent ore will cost $\frac{432}{48} = 9$ annas per unit and cannot be sold at a profit unless the market rate exceeds

9 annas. For lower grade ores the position is still worse and it is obvious that the majority of the Mysore ores require either high rates or low working expenses and freights to make them profitable. In some cases a rate of 2½ to 5 annas per unit may be obtained for the iron in the ore and if silica and phosphorus are low it may sometimes be possible to export ores containing 40 per cent or less of manganese under favourable conditions.

UTILIZATION OF MANGANESE ORE.

Manganese ore is put to a large variety of uses of which the preparation of various alloys of iron and manganese known as spiegel-eisen and ferro-manganese is far the most important and takes some 80 to 90 per cent of the whole output of the world. Manganese is also added to steel up to a proportion of 20 to 30 per cent and yields a material combining great toughness and hardness which is used for special purposes such as tramway points and crossings, rock-breakers, rolls, gun shields, etc. Various bronzes and other alloys are made with copper, aluminium, zinc, etc.

As an oxidiser manganese is used for the preparation of chlorine and bleaching powder, decolouring glass and manufacture of permanganates. It is used as a colouring material for calico, glass, pottery and paints and for various minor chemical and manufacturing purposes.

Spiegel-eisen and Ferro-Manganese.

Alloys of iron and manganese containing from 12 to 30 per cent manganese are usually called spiegel-eisen and those from 30 per cent upwards are called ferro-manganese. The most usual alloys are 12 and 20 per cent spiegel and 80 per cent ferro and these are made by smelting manganese ores with coke in blast furnaces, in much the same way as pig iron is smelted from iron ore, only that the output of the furnaces is much less and the consumption of fuel much greater than in the manufacture of iron. Spiegel contains 4 to 5 per cent of carbon and ferro 6 to 7 per cent of carbon and they are added

to molten steel, either in the furnace or in the ladle, in order to recarburize the steel to the extent required by the manufacturer. Spiegel is used chiefly for steel made by the Bessemer process and ferro in open hearth steels.

In addition to the recarburizing action the manganese purifies the steel by removal of oxygen and most of the manganese is converted to oxide and passes into the slag. It is usual to add sufficient alloy to leave a small excess of manganese in the finished steel to improve the rolling. On the average a total of about 3 per cent of manganese is required per ton of steel made and this accounts for the greater portion of the total production of manganese ore.

Manufacture in India.

With the exception of a few thousand tons of ore used in the iron and steel furnaces in India as a desulphuriser, practically the whole of the Indian output is sent to Europe where the greater part is converted to spiegel and ferro. The market value of the spiegel and ferro is probably from 3 to 5 times the value in India of the ore from which it is produced. The latter value has averaged over Rs. 1·20 lakhs annually during the past 5 years and the difference between this and the value of the manufactured article is represented as a very serious economic loss to India which could be reduced by manufacture in India on a large scale. Fermor has discussed the problem of manufacturing ferro at Sini on the Bengal-Nagpur Railway from the 52 per cent ores of the Central Provinces on the following basis:—

Materials required.		Rs.	a.	p.
1·9 tons ore at Rs. 22-8-0 per ton	...	42	12	0
2·5 tons coke at Rs. 16 per ton	...	40	0	0
1·0 ton limestone ...	...	5	0	0
Total materials	..	87	12	0

If we add Rs. 12-4-0 for fixed charges, labour, etc., the cost of manufacture comes to Rs. 100 per ton which is about equal to the cost of manufacture in England with imported ore. To send the ferro to markets in England and Europe would

probably cost Rs. 30 for rail and sea freights, dues, etc., and the cost of packing in barrels would probably be considerable and the prospects of selling at a profit in those markets does not seem very promising. In America the price is said to have averaged Rs. 191-12-0 from 1901-1907 and it would seem that even after allowing for packing, transport charges, etc., it should be possible to deliver Indian ferro at Pittsburg for less than that price, but the same argument would apply to ferro manufactured in England and the shipping expenses would probably be less from England than from India. Since the period quoted the average import value into America has been considerably lower—about Rs. 150 in 1913. It is possible that a material reduction might be made in the cost of ore and coke especially in the case of a company using its own ore and fuel and the problem is worth further attention in specific cases.

There is very little demand for ferro in India itself, probably not more than a couple of thousand tons a year, but it will probably increase somewhat in the near future. No doubt this could be supplied from India at a considerably lower figure than it can be imported for. The imported ferro costs some £10 to 11 per ton f.o.b. English ports to which must be added some Rs. 40 for transport, dues, import tax, etc., making the cost in India about Rs. 200 per ton.

The most serious point for consideration is the high percentage of phosphorus in the Indian ore and coke. The ore from the Central Provinces contains about 0·09 per cent P and Indian coke, such as that used at Sakchi, contains some 14·7 per cent of ash carrying, 0·93 per cent P. Coke with lower phosphorus may be available, but if we take the above figures and assume that all the phosphorus goes into the ferro we get the following figures :—

1·9 tons ore (0·09 per cent P)	=0·0017	tons P
2·5 tons coke (0·136 per cent P)	=0·0034	,,
Total ...	0·0051	

or 0·51 per cent P in the finished ferro.

It has been stated that it is not desirable that the P should exceed 0·22 per cent in an 80 per cent ferro and though doubtless this amount is often exceeded the fact of a very large increase as indicated above would diminish the value of the local ferro or cause a more expensive ferro to be preferred.

It has been necessary to consider the above few facts in connection with our gigantic neighbour before discussing possibilities in Mysore. If we had to enter into competition with a product made in British India on a large scale the position would be hopeless just as it is hopeless for Mysore to make ordinary pig iron in competition with Sakchi. Just as in the case of iron and steel the only chance for Mysore lies in the production of a high class product and we have two factors which favour this, *viz* :—an ore low in phosphorus (0·05 per cent or even less) and charcoal fuel which is practically free from phosphorus—with the result that we could produce a ferro (77 per cent) with not more than 0·1 per cent P.

Manufacture in Mysore.

We will assume that charcoal can be obtained although, as pointed out already, the supplies are small and may all be required for iron smelting. We will also assume that ferro and spiegel can be smelted in a charcoal furnace though we have no definite information that this has been done.

Charcoal Smelting.

A good deal will depend on the cost of ore, but if the smelting is done by a company like the Workington Company using its own ore the cost may be taken at Rs. 7 per ton at Shimoga for higher grade and Rs. 5 for lower grade.

The following approximate estimates contemplate the production of 5,000 to 8,000 tons of 77 per cent or 60 per cent ferro or 10,000 tons of 30 per cent spiegel.

For 77 per cent ferro we assume ore containg 48 per cent Mn. and 8 per cent Fe.

For 60 per cent ferro we assume ore containing 35 per cent Mn. and 17 per cent Fe.

For 30 per cent spiegel we assume ore containing 30 per cent Mn. and 24 per cent Fe.

TABLE 13—*Cost per ton of Ferro and Spiegel in Mysore.*

	77 per cent Ferro		60 per cent Ferro		30 per cent Spiegel	
		Rs.		Rs.		Rs.
Manganese ore ...	2 tons at Rs. 7.	14	2 tons at Rs. 5.	10	$1\frac{1}{4}$ tons at Rs. 5.	$6\frac{1}{4}$
Iron ore ...	...	...	...	...	12 cwt. at Rs. 3.	$1\frac{4}{5}$
Charcoal ...	$2\frac{1}{4}$ tons at Rs. 25.	57	2 tons at Rs. 25.	50	$1\frac{1}{2}$ tons at Rs. 25.	$37\frac{1}{2}$
Limestone ...	8 cwt. at Rs. 5.	2	8 cwt. at Rs. 5.	2	8 cwt. at Rs. 5.	2
Labour ...		4		4		
Repairs and relining.		5		4		
Supplies and sundries.		3		3		$17\frac{1}{2}$
Management and supervision.		5		4		
Interest and depreciation.		6		5		
Total ...		96		82		65

The figures for management, interest, etc., are somewhat problematical and depend on quantity and on combination of the work with other work, but the variations which might arise are not likely to total more than a few rupees per ton.

The production of a 77 per cent ferro might not be advisable as we have not a very large supply of the higher grade ores and to use them locally might very seriously interfere with the export of much larger quantities of lower grade ores which the former help to bring up to a marketable standard. On the other hand the use of ores containing 35 per cent Mn. or less for the production of lower grade ferro and spiegel would be an unmixed blessing as these ores are practically useless for export and are often a waste product of the mining work.

Assuming that the smelting work is technically possible it remains to enquire whether we can sell these products at a profit. It is very doubtful if the products could sell in

European markets unless specially high prices were offered on account of the low phosphorus (0·1 per cent or less). To the cost price at Shimoga must be added:—

	Rs.
Railway charges to Marmugoa ...	7
Freight and insurance	20
Charges at destination	3
Packing (cost not known)	5
	35

For the 77 per cent and 60 per cent ferros this Rs. 35 will have to be added making the c.i.f. costs in England Rs. 131 and 117, respectively. In the case of the spiegel if packing is unnecessary we may reduce the freight by Rs. 5 and packing by Rs. 5 making the addition for transport, etc., Rs. 25 and the c.i.f. cost of the spiegel Rs. 90. In England the sale price cf 80 per cent ferro is about £9 or Rs. 135 per ton and that of 30 to 35 per cent spiegel about £5 to 6, or Rs. 75 to 90, per ton and it would therefore seem that the Mysore products could not be put on the market at less than the general selling prices so that no profit would remain unless special prices were obtainable.

There is practically no demand for 60 per cent ferro. We might sell a couple of thousand tons of 77 per cent in India in substitution of the 80 per cent now imported. The latter, as shown above, costs about Rs. 200 at Sakchi.

Mysore 77 per cent would cost:—

	Rs.	
At Shimoga	96	per ton.
Transport to Sakchi ...	25	
Total ...	121	

and this should leave a good profit even if costs went up owing to smaller output.

It would be more advantageous from many points of view if the steel works would use 60 per cent ferro and we do not think there is any real difficulty in doing so in open hearth furnaces.

The 60 per cent ferro would cost:—

		Rs.
At Shimoga	...	82
Transport to Sakchi	...	25
Total	...	107

It would be necessary to use 1⅓ tons of 60 per cent, costing Rs. 143, to replace 1 ton of 80 per cent, costing Rs. 200, which still leaves a good margin for profit.

In the case of places like China, Japan and Australia transport ought not to cost more than the figures given above for England and we should therefore be able to land the Mysore products there at about makers' prices in England with the packing and transport charges from England in our favour in the shape of profit.

These various suggestions are, we think, worth the attention of practical men, but as the technical and commercial problems involved are intricate and rather obscure we do not feel justified in recommending definite action without further advice.

It must not be forgotten that the supply of charcoal is limited and that the whole of the reputed supply has been allotted to the iron smelting scheme already discussed. It would be safer and sounder to embark on the iron scheme than on ferro and the latter might come in as an adjunct if the opening up of the forests shows that sufficient charcoal can be made available.

In default of sufficient charcoal would it pay to use electricity? For several years the use of electricity has been suggested and considered.

Specially high grade ferro is made in electric furnaces in Europe for special purposes and fetches very high prices. Some of this contains 90 to 95 per cent Mn. and less than 2 per cent, or even 1 per cent of carbon and sells at prices up to £100 or more per ton. The demand is, however, very small and is probably insufficient to keep a single furnace running for one tenth of its time.

Electric Smelting of Ferro-manganese.

The question we have to consider is whether we can produce a good or superior ordinary ferro at a price which will compete with charcoal smelting or at a price which will pay.

The following figures are based on such information as we possess, but the consumption of power and electrodes are doubtful points.

TABLE 14—*Cost of Electric Ferro (ordinary 77 per cent).*

	Rs.	a.	p.
2 tons ore at Rs. 7	14	0	0
7 cwts. charcoal at Rs. 25	8	12	0
7 cwts. limestone at Rs. 5	1	12	0
6,500 K.W. Hours at 0·2 as. per unit ...	81	4	0
Electrodes	6	0	0
Repairs and relining	5	0	0
Management, labour and sundries ...	9	0	0
Interest and depreciation	7	4	0
Total ...	133	0	0

Thus with electricity as low as 0·2 anna per unit the cost is Rs. 37 more than for charcoal smelting.

The quality might be superior and fetch a higher price than ordinary ferro, but even at the above cost we could place the product at Sakchi at Rs. 158 per ton as against Rs. 200 now paid. It looks as if such a process might have some chance of success if the power can be obtained at a simple meter rate of 0·2 anna per unit at Shimoga, but we are doubtful if this can be done.

It would be possible also to place an electrically made 60 per cent ferro at Sakchi for less than the equivalent now paid and this, as already pointed out, would be advantageous to Mysore.

Other Ferro Alloys.

In the event of the establishment of an electric steel refinery it would be possible, with the addition of suitable furnaces, to conduct large scale experiments in the production of various ferro alloys which might lead to commercial production on a small scale. Amongst these may be mentioned manganese-steel, ferro-silicon (Fe, Mn) silicon-spiegel (Fe, Mn, Si), ferro-chrome (Fe, Cr), ferro-titanium (Fe, Ti) and special titanium steels. The quantities which could be disposed of commercially would no doubt be small and the standing charges would be too high to render such work profitable if taken up as a separate enterprise, but it is quite within the bounds of possibility that some of these products could be made at a profit as accessories to the larger work contemplated for steel refining.

Chromium.

The various alloys and compounds of chromium used in the arts are obtained from the mineral *Chromite or Chrome Iron Ore.*

Chromite is a black to brownish non-magnetic mineral composed of the oxides of chromium and aluminium combined with oxides of iron and magnesium [$(Cr_2Al_2)O_3$, $(MgFe)O$]. The relative proportions of the various metals present vary considerably and the mineral is often associated with iron ores in which the amount of chromium may be only a few per cent.

High class chrome ore contains from 50 to 58 per cent of Cr_2O_3; the ore becomes less readily saleable as the proportion of chromium oxide decreases and there is little demand for ore containing less than 42 per cent with 5 per cent or more silica.

Distribution and Occurrence.

Chromite has been found during the course of survey work at many places in the Shimoga, Hassan and Mysore Districts. In most places it occurs as grains in altered amphibolites, pyroxenites and dunite but too sparingly to be of commercial value. It occurs more abundantly in the narrow Nuggihalli schist belt running S.S.E. from Arsikere for a distance of 20 miles. The rocks of the belt are largely hornblende and talcose schists with what are considered to be intrusive masses of amphibolite partly altered to potstones or talc schists.

The chromite occurs in the altered amphibolite in segregated patches associated sometimes with iron ore.

Low Grade Ores.

This chrome ore is of comparatively low grade (42 per cent Cr_2O_3) and consists of fine granular chromite in a talcose matrix and is of a dull

greyish black colour. The ore appears to occur in large quantities, but so far none of it has found a market. It might be possible to concentrate it up to 48 or 50 per cent Cr_2O_3, but the want of water in the area would be a serious difficulty and the crude ore might have to be removed to some place where water is available. An attempt was made some years ago by the Mysore Chromium Company to start a concentration plant but after considerable expenditure on a water dam, plant, etc., the project was given up as not feasible. If the comparatively high prices which ruled in 1913-14 are maintained after the war a concentrating project may be worth further consideration, but it must be remembered that the market for chrome ore is a difficult one and some definite assurance would have to be obtained as to the saleability of the products.

High Grade Ores.

Further south, in the Mysore District between Mysore and Nanjangud, a number of patches of ultrabasic rock have been found which carry veins, lenses and segregated patches of chromite. Of these the most important is a narrow strip of altered dunite (Olivine rock) or peridotite, which is now a brownish coloured serpentine, running north and south for a couple of miles near Shinduvalli a few miles east of Kadkola. The serpentine lies in gneiss (which is considered to be intrusive) and contains grains of chromite. For a distance of a mile or so along a line near the middle of the strip a number of small, nearly vertical, veins of solid chromite have been found which vary from an inch to a foot or more in thickness. Towards the southern end one vein widened out to a lens 5 ft. wide and below this other separate lenses were found to a depth of 40 ft. in open workings. Underground work is now in progress and at a depth of 86 ft. a lens or vein over 170 ft. in length and up to 9 ft. in width has been opened up as well as two smaller veins to the west of it. The ore is massive and of good quality and the lens is broken into slab-like blocks by vertical and horizontal veins of magnesite which also traverse the serpentine.

*

In addition to the ore which has been mined from the Shinduvalli Block a large quantity of pebbles or lumps of chromite has been picked up on the surface of the ultrabasic patches.

Supplies in Other Countries.

In considering the sale or use of Mysore ores and particularly in regard to the problem of concentrating the low grade ores we must bear in mind that large quantities of good ore are obtainable from other countries with which Mysore cannot compare as regards either quantity or quality. In Baluchistan chromite has been discovered in serpentine associated with basic intrusives of cretaceous age. It is reported that considerable quantities of ore can be obtained much of which will average 54 to 57 per cent of Cr_2O_3 and most of which can be obtained by open work mining at moderate cost. Little precise information is, however, available. Up to the present the output has been small as it has to be carried 50 miles on camels to a railway; but that difficulty can be removed by extension of the line and in that case we might expect a large and regular supply from Baluchistan.

New Caledonia has been for many years the chief source of high grade ores averaging about 55 per cent Cr_2O_3. The ore occurs in alluvial or surface deposits close to the sea and the mining and f.o.b. costs are low. There is some reason to believe that these deposits are approaching exhaustion, but other less easily worked deposits are said to exist.

In Rhodesia vast areas of serpentinized rocks carry quantities of chromite most of which is of moderate grade, 47 per cent being usually quoted for shipment. The quantity of high grade ore is not very large though much larger than in Mysore and there is said to be a very large amount of medium to low grade ore. Here again large quantities can be cheaply mined in open workings though this is offset by the long railway lead to a port (Beira which is some 500 miles from the Salukwe area).

In comparison with these fields the high grade ores of

Mysore are of very limited extent and the problem of concentrating low grade ores will, we fear, be a doubtful proposition for many years in the face of the large supplies of easily mined high grade ore obtainable from elsewhere.

Composition of Ore.

The ore from Kadakola area is of good quality and runs from about 48 to 53 per cent Cr_2O_3. There is also some lower grade ore comparable to that from the Nuggihalli belt near Arsikere. The latter occurs usually in altered talcose amphibolite while the better class ore appears to be confined to the patches of serpentinised ultrabasic rock associated with magnesite.

Table 15 gives a number of representative analyses of the ores kindly supplied by licensees.

Cost and value of Ore.

Most of the ore has been obtained hitherto from surface collections, shallow pits and open workings down to a depth of 40 ft. The contract rates vary from Rs. 2 to 5 per ton of stacked ore. With the adoption of underground work the cost of the ore will increase and it is not possible to say what it will be in future. Much of the ore has been sold f.o.r. Kadakola at prices ranging from Rs. 8 to 15 per ton. Export has been very variable and home market values have appreciated considerably during the past few years. Table 16 shows the quantities despatched and sold to the end of 1914 and the average market-rates in England for 50 per cent ore. The rate is generally subject to a variation of 2 shillings to 2*s.* 6*d.* per unit of Cr_2O_3 above or below 50 per cent. The prices are said to be controlled largely by an international combine and the market is far from being an open one.

Uses.

The greater part of the chrome ore production is used for the manufacture of chrome salts for dyeing and tanning. A considerable amount is used for the manufacture of ferro-chrome (alloy of iron and chromium) and the ore itself, either in lump form or crushed and pressed into bricks, is used as a refractory lining for furnaces.

TABLE 15—*Analyses of Mysore Chrome Ores dried at 100°C.*

No.	Cr_2O_3	FeO	Fe_2O_3	Al_2O_3	MgO	CaO	SiO_2	MnO	K_2O Na_2O	P_2O_5	SO_3	H_2O (combined)	Remarks
1	42·00	19·65	...	19·43	11·50	0·17	6·30	0·07	0·58	Trace	Nil	0·30	Low grade ore, Arsikere.
2	48·65	18·63	0·24	12·70	...	...	2·45	...	...	...	...	...	Bulk sample from Shinduvalli Block, Kadakola.
3	50·45	18·92	0·28	12·10	15·60	...	1·55	...	...	...	...	...	Sample ½ a mile north of No. 2. Nos. 2 and 3 contained adherent magnesite and could be further cleaned.
4	48·05	19·32	0·42	12·70	14·90	...	3·06	...	...	...	...	...	From veins and stacks East Gurur, Mysore District.
5	50·10	19·64	...	13·73	12·28	Trace	2·66	1·44	...	...	...	0·15 (loss)	Shipment, Kadakola ore.
6	50·78	16·97	0·50	14·55	14·30	0·75	1·00	0·55	...	0·03	...	0·62	200 ton shipment from Kadakola.
7	53·18	16·70	0·71	13·33	15·00	...	0·15	0·40	...	0·08	...	0·58	High grade sample, Kadakola.
8	51·70	17·34	0·49	13·80	14·60	...	1·00	...	...	...	...	...	Surface pebbles, Kadakola area.

There are no manufactures of chrome products in Mysore and it is difficult to say if there is any reasonable prospect of their being established. The absence of cheap supplies of alkali and sulphuric acid is a bar to the production of the salts which may or may not prove insuperable. The production of ferro-chrome might become possible as an accessory to electric steel refining as already pointed out. It is not easy to obtain any reliable or detailed information as to modern methods and costs of production. Chrome ore was, at one time, smelted with coke in small blast furnaces giving a ferro-chrome containing some 40 per cent of chromium and 10 to 12 per cent carbon. With special blast arrangements a 60 per cent ferro-chrome has been produced in the blast furnace. At the present time it is made entirely in electric furnaces of the Heroult or Girod type, and from carefully selected ore it is not a difficult matter to produce a 60 per cent ferro-chrome containing 6 to 8 per cent carbon which is worth about £20 to 25 per ton. For special work ferro-chrome containing up to 75 per cent chromium and 1 to 2 per cent carbon is now produced and is worth £60 to 70 per ton. We cannot however give details of the process. Practically pure chromium without carbon is produced by the thermite process of Goldschmidt by igniting a mixture of pure Cr_2O_3 and aluminium powder.

Although we cannot give exact details the following figures are probably not wide of the mark for the production of an ordinary 60 per cent ferro-chrome with 6 to 8 per cent carbon.

	Rs.
2 tons of selected ore delivered at furnace at Rs. 20	40
Electric energy 8,000 K.W. Hours at 0·2 anna per unit	100
Electrodes	10
Charcoal, labour, repairs and fixed charges ...	40
Total ...	190

The output could not be large as the demand for ferro-chrome is not great, though it will probably increase. It must be remembered also that the probable supply of high grade chrome ore in Mysore is not large and that unless it was found possible to concentrate the low grade ores and utilize the concentrates the total duration of the work would be relatively short and the amortization charges for the plant would be correspondingly high. For these reasons it would be necessary to combine the work with other electro-thermal work in order to keep supervision and other fixed charges down to a reasonable limit. Under such conditions it looks as though ferro-chrome could be produced at a cost of not more than Rs. 200 per ton and if the price is Rs. 300 or more there should be a margin of profit after paying for transport, agency, etc. The paramount influence of the cost of electric energy is shown above and any material increase in the rate would render the work prohibitive.

TABLE 16—*Production of Chrome Iron Ore in Mysore, during the years 1907-1914.*

Year	Quantity sold . Tons	Calculated value, c.i.f. English Ports: Per ton 50 per cent basis	Calculated value, c.i.f. English Ports: Total rupees	Royalty	Remarks
		£. s. d.		Rs a. p.	*Note.* The sale value in Europe as given, is estimated on the prevailing market value for chromite on the 50 per cent basis at each quarter of the year. The value of the ore at the mines averages about Rs. 12 per ton at present. *The ore is all from the Mysore District with the exception of a 10 ton sample from Arsikere (Hassan District).
1907 ...	862	3 5 0	42,023	323 4 0	
1908 ...	5,785	3 0 0	2,60,325	2,244 14 0	
1909 ...	3,533	2 3 0	1,13,940	1,859 6 0	
1910 ...	...	......	......	......	
1911 ...	830	2 7 6	29,569	311 4 0	
1912 ...	...	......	......	.....	
1913 ...	...	......	... ..	......	
1914 ...	165	2 18 6	7,239	140 0 0*	
Total ...	11,175	......	4,53,096	4,858 12 0	

Other Metalliferous Minerals.

Minerals containing copper, silver, lead, zinc and antimony have been found in various places, but the quantities so far discovered are commercially unimportant and may be referred to very briefly.

Copper. Copper-pyrites and cupriferous iron-pyrites occur sparingly in quartz veins and quartzites and in some of the chloritic schists and traps. In a few places these minerals, and possibly others, have been broken up by weathering and circulation of water to shallow depths and from the solutions so formed, copper salts have been deposited in cracks, fissures or porous decomposed rock in the zone of weathering which may extend to a depth of 50 to 100 feet from surface. These salts are the green carbonate *malachite*, the blue hydrous sulphate *chalcanthite*, commonly known as *Blue Vitriol* and sometimes various silicates of copper appear to be present. At Ingaladhal, 5 miles south-east of Chitaldrug, there are some old workings in the side and top of a small hill from which fibrous specimens of chalcanthite can still be obtained in the form of incrustations or small veins in a decomposed gritty schist which is probably an alteration of the gray trap of Chitaldrug. The mineral was doubtless more abundant in the patches excavated by the ancients but at present very little remains and prospecting work has failed to disclose anything of the nature of a body of copper ore. It is probable that the mineral which now occurs in the walls of the old tunnels is of comparatively recent formation and is formed by the oxidation and leaching of traces of copper sulphides from the mass of the rock.

Malachite has been found in tufts of slender acicular prisms in a thin vein in quartzite near Kaidall, 10 miles south

of Davangere, Chitaldrug District. A surface sample gave 17·5 per cent copper, but some prospecting pits showed that the ore did not extend more than a few feet in any direction.

Copper carbonate occurs in the quartzite conglomerates to the north and north-east of Chikmagalur in the Kadur District, but a large number of samples showed that the copper never amounted to more than a heavy trace.

Traces of copper carbonate have been found at Kolur, 3½ miles east of Maddur, Bangalore District. In the Nanjangud Taluk, 1¼ miles S. S. E. of Biligere, pieces of green copper ore were found in the soil and some pits have been sunk to a depth of 40 feet under a prospecting license. The rock is a steeply dipping decomposed gneiss with an interbanded dolerite dyke of a few yards in width. The latter is considerably decomposed and shows strings and patches strongly impregnated with carbonate of copper. A piece of the gneiss (O/980) gave 0·25 per cent copper. A greenish grey sample (O/981) which may be a bleached portion of the dyke or some other trap gave 9 per cent Cu. and a dark brown ferruginous ore containing green carbonate and red oxide gave 24·32 per cent Cu. with 18 dwts. 15 grs. of silver. Sufficient work has not been done yet to enable one to judge whether any body of ore exists or which particular type of rock in this complex was the original home of the copper salts which now impregnate the various materials.

Silver.

There are traditional rumours of silver having been found in Mysore and names like Bellibetta (Silver Hill) are supposed to record such occurrences though no trace of silver ore is now to be found. Some small quantities of argentiferous galena, containing up to 130 ozs. of silver to the ton, have been found and are mentioned below under lead. It may not be generally known that the ore of the Kolar Gold Field contains silver which is recovered with the bar gold and afterwards separated during the final refining process. The bar gold contains from about 5½ per cent to 9½ per cent of silver, the average being about

7·85 per cent. An estimate based on the gold returns shows that up to the end of 1914 the Kolar Field has produced about 8,84,532 ozs. of fine silver valued at 18 lakhs of rupees. The annual production based on the figures of 1913 is now about 44,500 ozs. valued at Rs. 82,000.

Lead.

A small quantity of argentiferous galena (lead sulphide) was discovered by Mr. Sambasiva Iyer about a mile S. E. of the village of Kurubarmardikere in the Chitaldrug Taluk. The ore occurs in small stringers from ¾ to 1½ inches thick in gritty calc-chlorite schists which are probably alterations of the gray trap. There are only a few short stringers and some pits failed to reveal any tendency to increase in size or number. The clean ore assayed 134·65 ozs. of silver and 72·29 per cent of lead, but the quantity is very limited and the expense of extraction would be too high to permit of profitable working.

In a few places a little galena has been noticed in quartz reefs, for instance:—just west of the ghat section on the road to Hiriyur close to Chitaldrug town; on the east slope of Nisanigudda, near Nakikere, Hiriyur Taluk; and to the north-west of Arothekoppal in the Tirumakudlu-Narsipur Taluk. It is also found sometimes in the gold quartz of the Kolar Field and in other places where gold mining has been tried, but in none of these cases has any noteworthy body of ore been disclosed.

Zinc.

The mineral Blende (sulphide of zinc) has been found in the Kolar Mines and in some old workings such as those at Bukkambudi in the Tarikere Taluk but only in comparatively small quantity. At Bukkambudi the talc-chlorite schists in the neighbourhood of the old working have mineralized streaks or bands containing finely divided sulphurets, such as galena, blende and iron pyrites, but the proportion of these is small and the mineralized zones of no great extent. In the old workings a few more highly mineralized bands occur in which the total concentrates would not average more than

about one per cent of the rock. The low grade and the complex character of the concentrates preclude any reasonable prospects of working even if the mineralized zones were of large extent and this does not appear to be the case. It has been suggested that richer patches existed and were worked by the ancients for silver, lead and zinc, but it is more than doubtful if they could have treated such a complex mixture which would be a difficult proposition even under modern conditions. The rock is veined with quartz and carries a little gold and it is more probable that the old workings were excavated on some patches or lenses carrying fairly rich free gold.

Antimony.

The existence of small quantities of Antimony ore, in the Chitaldrug District, has been known for many years and in 1888 some samples of stibnite are said to have been collected by Mr. Mervyn Smith and sent to the Mysore Exhibition. In 1899 Mr. Sambasiva Iyer during the course of survey found some specimens of antimony ochre (cervantite) in the same locality but only in small quantities. More than one prospecting license has been taken out since and a large number of pits sunk in the search for both gold and antimony but without any satisfactory results. Loose blocks of a quartzose rock containing stibnite and cervantite were found, but neither the amount nor the grade of the ore was sufficient to justify further work.

Before the war the price of antimony ore in England varied from £6-10-0 to £10 per ton, but during 1915 the price rose very considerably to 10 shillings per unit or about £25 per ton for 50 per cent ore and a quotation for delivery in Bombay went as high even as Rs. 8 per unit. These prices were therefore three or four times the normal price and Mr. J. Burr of Bangalore took out a license in the hopes that under these favourable conditions the available ore might be mined and sold at a profit. Prospecting work has shown that the ore occurs in veins and patches in a

quartzose rock in the chloritic schists. Veins of a couple of inches in thickness have been located with wider bulges or lenses up to a foot or so in thickness. The ore is mainly stibnite (sulphide of antimony) altering to cervantite (oxide of antimony). Much picking and dressing is required to obtain ore of moderately good grade and so far the proportion of dressed ore has not exceeded about 1 per cent of the rock excavated.

The following Table shows the analyses of dressed samples of the ore:—

TABLE 17—*Analyses of antimony ores.*

No.	1	2	3	4	5	6
SiO_2 ...	41·81	42·30	...	53·62	41·60	
Sb_2S_3 ...	...	53·10	...	...	1·57	
Sb_2O_4 ...	...	...	...	43·60	48·06	
Sb (total) ...	38·86	(37·70)	48·00	(34·4)	(37·00)	40·00
S	13·61	...	...	0·60	...	
Fe_2O_3 and Al_2O_3 ...	2·56	1·00	...	1·92	2·45	
SnO_2 ...	...	nil	...	...	3·60	
PbO ...	trace	nil	...	trace	0·44	
As	nil	nil	...	nil	nil	
Zn	...	nil	...	...	nil	
CaO, MgO, etc. ...	...	3·60	...	...	2·28	

In these analyses of the dressed ore, which have been kindly furnished by the licensee, Nos. 1, 2 and 3 are sulphide ores and Nos. 4, 5 and 6 are oxide ores. Nos. 3 and 6 have evidently been dressed rather more carefully, but on an average the sulphide ore is not likely to exceed 38 per cent antimony and the oxide ore 35 per cent antimony in dressed bulk samples. If some of the dressed ore can be sold so as to cover expenses, it will be worth while doing some further work on the chance of striking some richer material, but it is evident that even at the high prices now ruling the proposition is hardly likely to pay unless a

marked improvement takes place. If we take the high quotation of Rs. 8 per unit at Bombay for 38 per cent ore the ore would be worth Rs. 304 per ton and this has to cover the cost of bagging and transport amounting to at about Rs. 34 and leaving Rs. 270 to cover cost of mining, dressing and sundries. If, as is reported, it takes 100 tons of rock to yield 1 ton ore we have only Rs. 2-12-0 per ton to cover these charges and it is rather questionable if there would be any balance for profit. If then the question of making a profit is a doubtful one when the ore fetches Rs. 300 or so at Bombay, the proposition would certainly not be attractive in normal times when the ore would fetch only Rs. 100 or less and this accounts for the fact that it has been left alone for so many years. The grade of the ore body would have to improve considerably before work under normal conditions could be seriously entertained.

The high prices now ruling may make it possible to collect the float ore and to do certain amount of excavation, sorting and dressing and to recover most or all of the expenditure with the chance that the work so done may disclose some more valuable ore bodies.

II. Minerals used in Various Industries.

(a) Abrasive Materials.

The abrasive materials available in the State are the minerals corundum and garnet and certain varieties of rock used for the preparation of mill-stones, whetstones, etc.

CORUNDUM.

The mineral corundum consists of oxide of aluminium ($Al_2 O_3$). It occurs in hexagonal crystals usually in double-ended pyramids the faces of which are often curved and give the crystals the shape of an elongated barrel.

In colour it varies from ruby red through various shades of brown, blue, green and white and usually contains various impurities such as the oxides of iron and chromium and mica, pinite and other silicates. Crystals or grains are frequently surrounded with a micaceous shell or with pinite-like material or green to black spinel. When pure and clear the red varieties are known as rubies and the blue as sapphires. These clear gem varieties are practically unknown in Mysore.

Emery is a dark opaque corundum containing much oxide of iron. It is obtained chiefly from Greece and Turkey but does not occur in Mysore.

Distribution.

Corundum of various grades and colours is widely distributed in Mysore and the principal localities are shown on the enclosed map. They may be grouped as follows:—

In the Sringeri Jaghir small quantities of good ruby corundum occur. Occasional large crystals of brown corundum have been found further south in the ghat country.

A number of deposits are found to the west and south-west of Arsikere.

On the eastern side of the State there are several corundum bearing areas in the Pavagada Taluk.

A large and important series of deposits occur in the Maddagiri and Goribidnur Taluks and another group round about Mandya.

Several groups occur in the Hunsur and Heggaddevankote Taluks of the Mysore District.

Occurrence.

The mode of occurrence and mineral associations of the Indian corundums have been described by Holland in Part I of the Manual of the Geology of India. A description of a number of the Mysore types and localities will be found in a paper by B. Jayaram in Part II of Records, Volume XV., published by this Department.

Most of the corundum obtained in Mysore is in the form of loose grains and crystals picked up in the surface soil. These have been set free from the rocks in which they occurred originally by the decomposition of the rock masses under ordinary weathering influences and, along with some of the other harder and more resistant minerals, they are found in the residual mantle of soil. Considerable quantities of this loose corundum have doubtless been removed in past times. In more recent years the quantities obtained and exported are shown in Table 18 and in recent years the production has been between 2,000 and 4,000 cwts. a year. It is probable that the supply, at any rate of the better classes, is now less abundant or less easily obtainable than formerly.

In many places the mineral has now been found *in situ* in both decomposed and hard rock.

A comparatively small proportion of the output has been obtained by excavating the soft decomposed rock and pounding it with wooden mallets or tilt hammers. The harder corundum is then separated by sieving and picking, but the resulting product usually contains much adherent impurity which may amount to 30 or 40 per cent. Up to the present no attempt has been made to work the hard rock.

The corundum occurs in veins or bands of pegmatite,

syenite or granite which traverse the older gneisses. In many cases it appears to be an original constituent of such veins, but it is noticeable that in the majority of cases the gneiss contains included bands and patches of basic Dharwar rocks, such as hornblende and mica schist, hornblende and pyroxene granulites, pyroxenite and amphibolite and that the corundum-bearing veins are frequently associated, or in contact, with such patches and often entirely enclosed within some of the larger ones. In some cases there is evidence of segregation or enrichment near the contacts which is suggestive of mutual reaction and sometimes the corundum is within the basic rock, but in many other cases the corundum has all the appearance of a primary constituent of the acid vein.

Value.

It is difficult to ascertain the value of the mineral with any degree of accuracy. Licenses for collection are granted over large areas, the usual area being a taluk. The licensee pays the villagers for amounts collected by them from time to time and a certain amount of sorting and selection is done before the material is despatched to Madras. The cost of collection has tended to rise recently owing to a general rise in wages and the lessened abundance of material; on the average the cost of collection is now probably some Rs. 60 to 80 per ton. The ruby varieties are the most valuable and from Rs. 300 to 500 per ton has sometimes been offered in Madras for good grades. The amount obtainable is however small. The better classes of pink, brown and grey corundum may be worth from 100 to 250 rupees in Madras and other varieties 90 to 100 rupees. There is a large quantity of rather dull white to greenish corundum which is of little or no value and is distinctly softer than the better classes. It is probably a mixture of hydrous and anhydrous oxides and considerable quantities have been found in corundum-bearing rocks near Arsikere in the Hassan District and near Sargur in the Mysore District.

The pink to amethyst coloured corundum which was extracted from veins of decomposed rock near Kamasandra in

the Bowringpet Taluk is stated to have been worth 250 to 270 rupees at Madras and the product was far from clean mineral. Down to water level the cost of extraction was about Rs. 150 to 200 per ton.

Various samples which have been sent to England have been valued at from £8 to £30 per ton.

In Canada large quantities of corundum-bearing rock are mined, crushed and the clean mineral extracted. The annual production is about 2,000 tons and the average value £22 per ton. There the veins or bands, many of which consist of nepheline syenite, are of large dimensions and permit of cheap open quarrying on a large scale. As the output is considerable the mining and dressing charges are comparatively low and rock containing only from 5 to 10 per cent of corundum is treated. In recent years the average grade has approached 5 per cent.

Treatment.

For the preparation of clean corundum the rock or mineral is put through breakers and crushers and graded into various sizes by means of screens.

The coarser sizes are then treated in jigs and the finer materials on various types of shaking tables.

The middlings or mixed materials from the jigs are crushed finer and retreated with the recovery of further corundum. In some cases a final treatment with magnetic separators is necessary to remove heavy magnetic minerals which come through the process with the corundum.

The amount of machinery required is considerable and the question of mining and dressing costs is largely one of quantity.

It would no doubt be very desirable to crush and dress the Mysore corundum locally and to export clean and carefully graded products instead of raw unclean mineral, but the quantities produced at various centres are probably much too small to warrant the expense of the plant and supervision. Even the total output from the State is small for any modern treatment plant.

As most of the corundum has to pass through Bangalore on its way to Madras, it might be feasible to put up a single treatment plant at Bangalore and purchase the whole output of the State. A better market for the finished and graded product might be obtained and the development of the output would very likely be encouraged by a regular demand.

This applies to the output of loose corundum crystals, but the plant would afford opportunity for experimental testing of some of the corundum-bearing rocks of the State. If some of these proved promising, further prospecting would be encouraged and some sufficiently large deposit might be found to warrant the erection of a plant or partial plant at the mine for the rough treatment of the rock.

The prospects are very problematical and various samples have been obtained and sent to America for trial and opinion. It must be remembered also that artificial abrasives such as carborundum, alundum, etc., are yearly becoming more serious competitors, and it is probable that carborundum can be produced for £27 or less a ton and will be preferred to corundum for most purposes.

TABLE 18—*Production of corundum in Mysore and the royalty realized thereon during the years 1900 to 1914.*

Year	Quantity exported	Average value at the mine	Royalty
	Cwts.	Rs.	Rs.
1900	1,602	4,806	238
1901	1,490	4,470	261
1902	171	513	67
1903	...	...	...
1904	...	...	...
1905	1,299	3,897	685
1906	2,064	8,256	1,088
1907	1,086	4,344	559
1908	124	496	65
1909	436	1,744	229
1910	2,152	8,608	1,134
1911	2,505	12,525	1,020
1912	2,926	14,630	1,522
1913	4,150	20,750	2,179
1914	1,604	8,020	845
Total ...	21,609	93,059	9,892

GARNET.

The garnets are a series of complex silicates containing two or more of the metals aluminium, iron, calcium, magnesium, manganese and chromium. They occur in rounded crystals and grains and are very variable in colour, the commonest colour being pink, red or brown.

Distribution.

In Mysore red to brown garnets occur in a variety of rocks in many places of which the following may be mentioned.

In the Shimoga District they occur plentifully in mica schists lying in the gneiss between Agumbe and Koppa.

In the Kadur District near Sampigekan and Durgadhalli in hornblende schist and gneiss.

In the Hassan District near Yennehole Ranganbetta (Hole-Narsipur); near Bherya (Yedatore) where dull coloured and flawed crystals up to 3 inches in diameter are found; in the Manjarabad Taluk along the Kemphole and Adhalla streams and at Balekal, Kagneri, Murkangudda and Maranhalli in some of which places very large quantities of loose garnets can be obtained which have been weathered out of the hornblendic schists and gneiss. Most of these are small and some are clear and transparent.

In the Bangalore District pink garnets occur in pegmatite near Salhunse and small clear crystals and pebbles at Maralwadi in the Kankanhalli Taluk.

In the Kolar District there is a good deal of garnet sand in the streams near the corundum pits near Kamsandra.

In the Heggaddevankote Taluk of the Mysore District garnets occur freely in Kyanite schist and gneiss and loose pieces and fragments about ¼ inch in diameter can be washed from the surface soil. In addition to the above the mineral often occurs as a minor constituent in a variety of rocks.

Uses.

The larger clear varieties are used as gem stones. The Mysore minerals are not sufficiently large for the purpose when clear and of good colour, or when large they are dull in colour or much flawed

and it has not been found possible to find a market for the stones. In several of the States of Rajputana a purple coloured garnet, belonging to the variety Almandite (iron-alumina garnet), is worked as a gem stone. The average yearly production for India from 1909-1913 is reported to be 298 cwts. valued at £1792(1). The average value in different localities varies from about Rs. 30 to Rs. 150 per cwt.

There is a limited demand for garnet as an abrasive material, mostly for use in the leather and wood trades. The chief market is in the United States where the total consumption is some 4,000 to 5,000 tons per annum almost the whole of which comes from the Adirondack region of New York. The average value of the cleaned and graded mineral is about Rs. 90 per ton and about Rs. 105 for the best grade of crystal. The Adirondack mineral is said to be of the Almandite variety and to be somewhat harder than usual. Its chief value depends on the possession of a fairly well defined cleavage or parting which causes the mineral to break up into flat plates with sharp edges which tend to renew themselves by fracture during use. More usually garnet tends to break with a rough or conchoidal fracture and to wear round at the edges and such minerals have comparatively little value. For the same reason the fine rounded grains which occur abundantly in many streams have little value. Several tons of such material have been collected at Kamsandra which cannot be disposed of.

Various samples of Mysore garnets have been sent to England for valuation and in the majority of cases are reported to be of little or no value.

A large sample collected and washed from the Heggaddevankote Taluk was valued at £4 per ton, but as the cost of collection was considerably higher than this figure the licensee abandoned the work.

Garnets obtained from the Manjarabad Taluk under a

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(1) Records of the Geological Survey of India, Vol. XLVI, Page 271.

prospecting license are reported to have been valued at from Rs. 45 to Rs. 90 per ton in England, but as no further progress has been made it is probable that the work was not considered to be remunerative. It is very doubtful if there is any large demand for garnet for abrasive purposes outside the United States and it is very doubtful if the Mysore mineral would pay to extract, grade and put on the market in small quantities at current prices.

In recent years there has been a small output from Spain which, it is believed, can be produced at considerably less than the American figures quoted above.

MILL STONES.

From several places in the Honnali Taluk, notably from Beesokalmatti—a hill north of Chik Gonigere—and from a hill north-west of Hosakoppa, large blocks of gritty schist are quarried and made into flat circular mill stones for grinding food stuffs and some of the finer grained varieties are used for whetstones. Larger blocks of tough calcite-chlorite trap are made into rollers for mortar mills near Basavapatna in the Channagiri Taluk. The work is carried on by the woddars of the Shimoga District and there is said to be a good demand for the stones in the Chitaldrug, Tumkur and Hassan Districts. In a Departmental report made in 1901 it was estimated that about 1,200 tons of stone, valued at Rs. 5,400, was used during the year in the Honnali Taluk. In the Hassan District certain varieties of potstone are stated to be used for mill stones and in Bangalore mill stones, road rollers and stones for mortar mills are made from selected portions of the granite and gneiss. In all these cases the materials are used to supply certain local demands, but none of them appear to possess any particular merits for high class grinding work and their use is chiefly a matter of local convenience.

(b) Refractory Materials.

MICA.

Character and uses.

The micas are essentially silicates of alumina and potash sometimes containing also magnesia, fluorine, lithia or soda. They are transparent flexible minerals occurring as flakes, sheets or thicker "books" and are capable of being split into indefinitely thin sheets owing to a very highly perfect cleavage. In colour they vary from white to red, brown and black.

The principal varieties are:—

Muscovite.—White to reddish brown;

Phlogopite.—Reddish or "amber" mica;

Biotite.—Black.

The two former are of commercial importance and represent the materials exported from India. The mica found in Mysore is muscovite which is usually dark coloured in thick books and light reddish brown in thin sheets.

Owing to its flexibility, transparency and infusibility it is used for lamp chimneys, stove doors, etc. Its chief use is however as an insulator for the manufacture of electrical machinery for which purpose it is necessary that it should be free from inclusions, spots and flaws.

The larger books are split to about the thickness of cardboard and the rough edges and flaws trimmed off with shears so as to give clean sound squares or rectangles with sides from one to two inches long up to several inches in length. Occasionally pieces over one foot square are obtained. The smaller pieces of irregular shape are trimmed to various round or oval shapes which are eventually split into very thin laminæ and cemented together with shellac to form large sheets known as "micanite." This artificial micanite yields

a fairly good insulating material in lieu of large cut sheets, which are scarce and expensive, and has permitted the utilization of large quantities of scrap mica from the waste dumps of mines.

Some of the scrap mica produced by trimming and cutting of sheets is now finely ground and finds some sale for boiler and pipe lagging, fire proofing, lubricants, wall paper and paints.

Occurrence.

The micas occur in small flakes in many rocks chiefly those of a granitic or gneissic character. The larger books of commercial value are practically confined to large veins of coarse pegmatite which traverse or are asssociated with intrusions of granite and gneiss. In India the veins usually traverse mica schists or schistose gneisses, while in Mysore they are mostly in granitic gneiss. India is one of the most important mica producing countries of the world the chief centres of production being Behar and Orissa and Nellore.

In Mysore books of mica, up to 7 or 8 inches in diameter, have been found in several places, but the distribution is very erratic and much of the material is flawed or spotty and of rather low quality. The principal localities are the following:—

Hassan District.—The Kabbur Block (P. L. 350) near the 30th mile on the Yedatore-Hole-Narsipur road. At Sitapur hill, 6 miles S. W. of Hole-Narsipur.

Mysore District.—At Mundoor, 3 miles north of Saligram (P. L. 346.)

Two furlongs E. of Undivadi, near Kannambadi.

South of the 16th mile on the Kannambadi Road.

Near Vadesamudra—7 miles N. E. of French Rocks. (P. L. 436.)

Near Tagadur—7 miles E. of Nanjangud (P. Ls. 408 and 409.)

Sringeri Jahgir.—Near Kikri—It is reported that 23,568 lbs. of plates, rounds and splittings were obtained

from about 180,000 lbs. of undressed mica, but not sold yet. Work has been abandoned for sometime.

Output.

Attempts have been made, from time to time, to work some of these deposits and repeatedly abandoned owing to the irregular distribution of the mineral and the small quantity of saleable mica obtainable. It is probable that the amount of saleable mica recovered does not exceed 10 per cent of the total amount extracted.

Work is now being carried on at Kabbur, Mundoor and Vadesamudra.

The following Table gives the output to the end of 1914 the greater part of which has come from Kabbur. The output from the Sringeri Jahgir is not included.

TABLE 19—*Output aud Value of Mica.*

Year	Quantity exported lbs.	Value at Madras Rs.	Value per lb.
1911 ...	2,028	876	6·91 annas.
1912 ...	5,062	2,308	7·28 „
1913 ...	1,000	994	15·90 „
1914 ...	5,477	2,514	7·35 „
Total ...	13,567	6,687	7·88 annas.

Value.

Mica varies so much in size and quality that it is difficult to quote values which convey much information, while in Mysore the output has been so small and irregular and the grades so mixed that no very reliable figures are yet available.

The three principal producing countries are the United States, Canada and India and the following figures have been reported.

In the United States the value of sheet mica has been

about 9 to 10 annas per lb. for the past 10 years and scrap mica Rs. 30-50 per ton.

In Canada the output is almost entirely Phlogopite or "amber" mica. The export value for the past few years has been from 12 to 15 annas per lb.

Indian mica from 1908-09 to 1913-14 has been valued at an average of 10 annas per lb. rising to 11 annas at the end of the period.

The Mysore mica sold in England has varied from 2 annas to Rs. 2½ per lb. for the various grades exported.

Consignments sent to Madras have averaged from about 7 annas to 1 rupee with a general average of 7·88 annas per lb. It is very doubtful if profitable work can be carried on at these prices unless some better deposits are found. Further work is contemplated at Vadesamudra and Kabbur and there is at any rate a possibility that the yield of saleable mica may be somewhat improved.

ASBESTOS.

Two distinct types of mineral are included under the commercial term "Asbestos." The most important is the mineral chrysotile—a hydrous silicate of magnesia—which is considered to be a fibrous form of serpentine. It occurs in narrow irregular veins in serpentine or other ultrabasic rocks the fibres of the mineral lying perpendicular to the vein walls. The veins are usually from ¼ of an inch to 2 or 3 inches in width and this determines the length of fibre obtainable. The greater part of the world's supply of this material comes from Canada. Very little has been found in Mysore and then only in very thin unworkable veins in serpentine. The other forms of asbestos belong chiefly to the varieties tremolite and actinolite of the amphibole group and are essentially anhydrous silicates of lime and magnesia.

Characters and use.

The value of asbestos depends on the facility with which the mineral can be broken up into fine fibres and on the length and strength of

these fibres. Its usefulness depends very largely on the fact that the fibres are very infusible and consequently it is used very largely as a fire-proof or fire-resisting material. The longer and stronger fibres can be woven into fire-proof cloth and the shorter fibre, dust, etc., which is produced during milling is used for asbestos board, paper, tiles and plaster and also as a lagging or non-conducting covering for boilers, steam pipes, etc.

Occurrence.

So far none of the chrysotile variety has been found in Mysore in workable quantities but small veins have been noted in serpentine masses near Hole-Narsipur and Idegondanhalli in the Hassan District and near Shinganmane in the Shimoga District.

The amphibole variety of asbestos has been noted in several places and appears to be an alteration product of various amphibolites or other ultrabasic rocks in proximity to intrusions of granite or gneiss. The following places may be mentioned:—

Chitaldrug District.—N. E. of Mayikonda village; fibres stained reddish brown and hard.

Near Budihal, Gangigere in the Hosdurga Taluk.

Kadur District.—In a coffee estate near Mudsosi, Mudgere Taluk.

Near milestone $\frac{4}{16}$ on the Belur, Mudgere road.

Hassan District.—On the Kabbur Block (P. L. 350).

Near the 30th mile on the Yedatore Hole-Narsipur road. Several tons have been obtained from here as samples and a fairly large quantity is said to be obtainable. The mineral also occurs near Hole-Narsipur, Sunnakal Hosur and Idegondanhalli.

Bangalore District.—A small quantity of a white asbestos has been found at Avalhalli about 2 miles from Bangalore on the Mysore road.

Mysore Ditrsict.—Small quantities have been found near Nagamangala and 2 miles S. W. of Mandya. The occurrence of a larger deposit has recently been reported near Konur about 12 miles south-east of Nanjangud.

Value.

The values vary very greatly according to quality. The different grades of material produced from the Canadian chrysotile deposits vary from about Rs. 900 to Rs. 27 per ton with an average value of Rs. 90 per ton. A large number of grades are produced from the same quarry during the process of mining and milling. The average amount of merchantable fibre produced is about 6 per cent of the total amount of rock excavated. The output from the United States is comparatively small and is of the amphibole variety and is valued at from Rs. 30 to 45 per ton. The Mysore mineral occurs in bunches and aggregates of fibrous material and at Kabbur long fibrous sticks of several feet in length can be obtained which can be picked out practically clean. The material can be easily fiberized and reduced to a white fluffy mass which should possess some merits as an insulator, steam pipe covering and where strength of fibre is not essential. The great defect in all the samples is the brittleness and lack of tenacity of the fibres and a sample of several tons sent to London failed to find a satisfactory market and was eventually sold at a little under Rs. 20 per ton.

The cost of the crude material delivered on the railways is said to be from Rs. 35 to 50 per ton.

The material obtained so far has all come from close to surface where the rock is much decomposed and this may account for the excessive brittleness of the asbestos fibre. In view of the increasing demands for asbestos it would be worth while to sink some of the pits deeper and ascertain whether the fibres become stronger while retaining sufficient facility for easy separation.

MAGNESITE.

Character and mode of occurrence.

Magnesite is the normal carbonate of magnesia ($Mg\ CO_3$) and occurs, from a commercial point of view, in two distinct varieties or types having very different modes of origin.

These types are sometimes distinguished by the terms "massive magnesite" and "crystalline magnesite."

The massive type only is found in Mysore and important deposits occur at Salem in the Madras Presidency and in the island of Euboea (Greece). Less notable deposits occur in many other countries.

This type occurs as a net work of veins in ultrabasic rocks of a serpentinous character derived from the alteration of dunites, peridotites, amphibolites, etc. The mineral probably results from the breaking up of the magnesian silicates by heated vapours or solutions containing carbonic acid with the production of magnesite which is deposited as veins in joints and fissures of the rock. A little of the silica is deposited with the magnesite in the form of chalcedony and the rest is removed in solution and may have been deposited elsewhere as quartz veins.

In Mysore the original ultrabasic rocks appear to have been intrusive dykes or masses in the Dharwar Schists and to have been intruded subsequently by portions of the Peninsular gneiss from which the heated solutions and carbonic acid were probably derived.

The magnesite is a hard white massive material with a rough to conchoidal fracture, something like broken procelain. Its value depends on the absence of impurities, particularly lime and iron, on the ease with which it can be separated from the enclosing rock and on the proportion of clean mineral obtainable to the total rock excavated.

The crystalline type of magnesite occurs only in Austria and Hungary and appears to be of the nature of a crystalline limestone or dolomite, of sedimentary origin, in which lime has been almost completely replaced by magnesia by subsequent chemical alteration.

For practical purposes the two types of magnesite are distinguished by the amounts of iron and alumina they contain and by their different behaviour during burning. As a commercial material the massive type contains less than 1% of iron

oxide while the crystalline type contains some 3 to 6 % of oxides of iron and alumina. The former burns to a white material which is usually only lightly burnt or calcined; the latter is always dead-burnt at a high temperature and yields a brown granular material which is used either as such or in brick form for furnace linings.

Distribution.

The various points at which magnesite has been found in Mysore are indicated on the enclosed map.

The principal deposits occur in the Mysore District between Mysore and Nanjangud. Of these the most important are at Dod Kanya and Dod Katur while other less important or poor deposits have been found near Shinduvalli, Talur, Solepur, Mavinhalli, Gurur and Kupya.

In the Hassan District relatively unimportant deposits have been found to the east and south-east of Hole-Narsipur and in the Arkalgud Taluk.

At Dod Kanya there is a patch of serpentinized rock, about three-quarters of a mile long by one quarter wide, which is much traversed by white veins of magnesite many of which appear on surface. The veins vary from mere threads up to several inches with occasional swellings up to several feet in thickness. From the prospecting work done it is seen that the veins tend to occur in two sets, one more or less vertical and the other horizontal or slightly inclined. Several of the larger masses belong to the latter set. It is probable that a considerable proportion of the whole mass would yield about one ton of magnesite for each 10 tons of rock excavated and that the total amount of workable magnesite would amount to several hundred thousand tons. The other deposits are less extensive or would yield lower proportions of mineral.

Composition.

A number of analyses have been obtained, chiefly from the Dod Kanya area (P. L. 404) and these are shown in Table 20 together with a few representative analyses from other places for comparison.

TABLE 20—*Analyses of Magnesite from Mysore and other localities.*

<table>
<tr><th>Serial No.</th><th>Insol. residue.</th><th>SiO_2</th><th>Fe_2O_3</th><th>Al_2O_3</th><th>CaO</th><th>MgO</th><th>Remarks</th></tr>
<tr><td></td><td></td><td></td><td colspan="2">(Mysore samples)</td><td></td><td></td><td></td></tr>
<tr><td>1</td><td>...</td><td>2·44</td><td colspan="2">0·56</td><td>16·29</td><td>32·48</td><td>Surface material contaminated with Kankar. Dod Kanya.</td></tr>
<tr><td>2</td><td>2·82</td><td>...</td><td colspan="2">0·57</td><td>6·56</td><td>40·88</td><td>,, ,, ,, ,,</td></tr>
<tr><td>3</td><td>...</td><td>5·64</td><td colspan="2">1·18</td><td>1·24</td><td>43·52</td><td>Large sample from stacks ,,</td></tr>
<tr><td>4</td><td>1·78</td><td>...</td><td colspan="2">0·07</td><td>0·45</td><td>46·49</td><td>Clean magnesite, 8 ft. below surface $\left(\frac{\times}{426}\right)$,,</td></tr>
<tr><td>5</td><td>3·60</td><td>...</td><td colspan="2">0·12</td><td>0·48</td><td>45·25</td><td>,, ,, 6 ft. ,, $\left(\frac{\times}{425}\right)$,,</td></tr>
<tr><td>6</td><td>2·72</td><td>...</td><td colspan="2">0·12</td><td>0·52</td><td>45·84</td><td>,, ,, 9 ft. ,, $\left(\frac{\times}{424}\right)$,,</td></tr>
<tr><td>7</td><td>0·75</td><td>...</td><td colspan="2">0·12</td><td>0·35</td><td>47·12</td><td>,, ,, 12 ft. ,, $\left(\frac{\times}{423}\right)$,,</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">(Foreign samples)</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>...</td><td>0·29</td><td>...</td><td>0·65</td><td>0·88</td><td>46·42</td><td rowspan="2">Salem, India. Quoted by H. M. Dains, F.I.C., etc., in the Journal of Chemical Technology; 1912.</td></tr>
<tr><td>9</td><td>...</td><td>1·17</td><td>...</td><td>0·14</td><td>0·78</td><td>46·28</td></tr>
<tr><td>10</td><td>...</td><td>1·63</td><td>1·19</td><td>0·17</td><td>1·44</td><td>45·75</td><td rowspan="2">Greecian ,, ,, ,,</td></tr>
<tr><td>11</td><td>...</td><td>3·10</td><td>0·30</td><td>0·80</td><td>...</td><td>...</td></tr>
<tr><td>12</td><td>...</td><td>3·24</td><td>2·97</td><td>1·14</td><td>0·82</td><td>42·80</td><td rowspan="2">Styrian ,, ,, ,,</td></tr>
<tr><td>13</td><td>...</td><td>0·92</td><td>...</td><td>4·30</td><td>1·68</td><td>42·43</td></tr>
</table>

At surface the Mysore magnesite is sometimes contaminated with lime kankar which raises the lime contents so high as to render the material useless for refractory purposes. The kankar is brown in colour and can be removed by dressing. A few feet below surface it disappears, but care has to be taken to clean the magnesite from serpentine, amphibolite and chalcedonic silica.

When properly dressed the Mysore material compares favourably with that from Salem and Greece.

USES OF MAGNESITE.

Raw Magnesite.

Raw magnesite is used in America for the production of carbonic acid gas (CO_2). The magnesite is heated in iron retorts thereby driving off the CO_2 which is collected and compressed in cylinders for the manufacture of ærated waters, etc. The residue in the retorts is calcined or caustic magnesia and is sold for the manufacture of refractory bricks, cement, plasters, etc. This use of magnesite as a source of CO_2 is said to be decreasing as the residual magnesia is often insufficiently burnt for the purposes for which it is required and unless it can be sold the manufacture of CO_2 in this way would not pay.

Magnesite is sometimes treated with sulphuric acid for the production of CO_2 and Epsom Salt is prepared from the residual solution. A note on this will be found in the section on the materials used for Agricultural and Chemical Industries.

Caustic Magnesia.

Caustic magnesia, also called calcined or lightly burnt magnesia, is obtained by burning magnesite in kilns in very much the same way as limestone is burnt to quick-lime. The burning may be conducted in bottle kilns with an admixture of coal, coke, wood or charcoal, but this has the disadvantage of introducing impurities from the ash of the fuel. Where purity is essential it is burnt in kilns with external fire-boxes or fired with gas. At Salem where high class caustic magnesia is produced the

kilns are vertical, continuous feed, shaft kilns fired with producer gas made from Bengal coal. Magnesite is said to part with its CO_2 at a lower temperature than limestone, but much depends on physical character and on the amount of CO_2 which may be permitted to remain in burnt stuff. If the magnesia must not contain more than 2% of CO_2 the temperature requires to be 900° to 1000° C. for the Indian variety. After calcination the magnesia will absorb water and CO_2 from the air and will set into a moderately hard paste if slaked with water. The caustic magnesia is used very largely as a filling for paper and wood pulp and for the preparation of Sorel or "Oxychloride" cement for the production of which it is mixed with a strong solution of magnesian chloride. The cement is extremely hard and will carry several times as much sand or stone as lime or Portland cement and at the same time shows much greater resistance to crushing. It is said to be suitable for indoor work and to deteriorate on continued exposure to the weather.

It is used for the preparation of artificial stone, grindstones, mill stones, etc., and is mixed with sawdust, cork, asbestos, talc, etc., for the production of floor tiles, complete floors, etc. It is believed that most of the magnesia from Salem is sent to Europe for these purposes and the possibility of producing such a cement in Mysore for local use is worth attention. A good deal will depend on securing a suitable supply of magnesium chloride and the bitterns from the Madras Salt Works have been suggested as a possible source.

Dead burnt Magnesia.

In order to dead-burn magnesite the CO_2 has to be almost completely driven off so that not more than from ½ to 1 % remains. In order to do this the temperature must be raised to from 1500° to 1700° C for which special kilns are required and a large expenditure of fuel. At this high temperature the magnesia shrinks and increases in density and will no longer absorb water or CO_2. In this form it is very refractory and is used as a basic lining for steel furnaces and electric furnaces. The

principal supply of dead-burnt magnesia comes from Austro-Hungary where the deposits of crystalline magnesite contain much more iron and alumina than the Indian and Greecian varieties. Owing to its physical character and composition the former can be dead-burnt at a temperature of 1500° C in continuous bottle kilns using producer gas or in rotary kilns using powdered coal. The resulting material clinkers or frits so that it is obtained in a granular form which can be thrown on to the bed of the furnace without getting blown away and it then frits together into a solid mass. Also, if moulded into bricks and fired it fuses together sufficiently to form hard strong bricks suitable for furnace work. It is still a very refractory material and for the above reasons there is a large demand for it for basic linings.

When we come to the massive variety such as occurs in Greece, Salem or Mysore a different problem is presented. The temperature required is much higher—about 1700° C-and this will probably necessitate special kilns of a regenerative type. Attempts to produce dead-burnt magnesia at Salem are understood to have been unsuccessful. Again, the material does not frit together, but falls into fine powder in which form it is unsuitable for furnace lining or manufacture of bricks. It is believed, however, that bricks are made from it for electric furnaces and that they are more refractory than those made from the Austrian magnesite; on the other hand they are brittle and would not stand the mechanical strains of open hearth furnaces. The problem of using Mysore magnesite for this purpose has been under investigation in consultation with the Tata Iron and Steel Works and the most practical solution appears to be to grind either the magnesite or calcined magnesia with a small quantity of iron oxide thereby reducing its infusibility and permitting it to frit to a material which can be used in a granular form or made into bricks. Experimental work has shown that good bricks can be thus made and the outstanding questions are those of cost and location of work.

From the prospecting work done on the Dod Kanya block it is probable that the cost of mining and sorting the magnesite will lie between Rs. 3 and Rs. 5 per ton of magnesite exclusive of supervision.

Cost of Mining.

It is very difficult to give any estimates of cost without a definite proposition as to quantities and character of the product required. The following figures may, however, be of some use to those who have the matter under consideration. The amount of coal required is about 20 to 25 % of the calcined magnesia, say about Rs. 5 per ton of calcine. If wood could be used the cost would be slightly less.

Cost of Calcining in Mysore.

TABLE 21—*Estimated cost of calcining magnesite in Mysore.*

Output 50 tons of caustic magnesia per month	Rs.	a.	p.
2¼ tons of magnesite at Rs. 4	9	0	0
Coal	5	0	0
Labour for burning	6	0	0
Bags and bagging	6	0	0
Supervision	5	0	0
Interest and upkeep of kiln	2	0	0
Royalty, rent and sundries	5	0	0
Total per ton of magnesia ...	38	0	0

This is a very rough estimate and the charges for supervision might have to be greatly increased if a high grade standard product was required. On the other hand, if the output was materially increased to a few thousand tons a year

the cost would come down to about half the above figure at which rate it might be just possible to place some on European markets.

Cost of dead burning.

Little precise information is available at present on this point. Either the magnesite or calcined magnesia would have to be ground and mixed with iron ore and then bricquetted and dead-burnt. Rotary kilns would not be desirable unless the output was large. The amount of coal required would probably be about 15 cwts. costing, say, Rs. 15, and the total cost of making dead-burnt magnesite in Mysore is likely to lie between Rs. 50 and Rs. 80 per ton. The cost of the Austrian material imported into India before the war was about Rs. 65 per ton.

It is doubtful if the dead-burnt material could be supplied to the north of India from Mysore as cheaply as it can be imported unless the output is large and the demand does not justify this at present. On the other hand, it is quite possible that manufactured bricks could be delivered at a lower rate than the imported article owing to higher packing and transport charges, etc. This point is still under investigation.

OTHER REFRACTORY MATERIALS.

Chromite.

Chromite, or Chrome Iron Ore, is in some demand as a refractory lining material for furnaces. The occurrence and distribution of the ores have been described already under Chromium. For furnace lining the ore is preferred in large lumps or brick-like blocks and it is believed that bricks are also made from the crushed powder. During the past year or so a regular supply of high grade Chrome Ore has been sent to the Tata Iron and Steel Works from Kadakola in Mysore. It is thought that there may be some use also for the lower grade ores from Arsikere in lump form and attempts are being made to find a market.

Potstone.

Potstone, or soapstone, is a soft tough greenish to grey rock composed largely of the mineral talc. It usually contains varying proportions of

mica, chlorite, serpentine, amphibole and pyroxene and the amount of the accessories or impurities determine the quality of the stone.

The fine, light coloured and comparatively pure soapstone which is used for gas-burners, production of talc powder, etc., has not been found in Mysore. The coarser textured greenish material is used locally for the manufacture of pots, pans and other fire-resisting utensils, but the most extensive use is as an ornamental building stone where intricate and delicate carving is required. Other uses are as electric switchboards and insulators and in the form of fine powder for cotton sizing, paper filling, lubricant, etc., but the suitability of the Mysore materials for these purposes has not been ascertained and the greater number of samples would appear to contain too much gritty material.

Varieties of potstone are widely distributed chiefly in the region between Arsikere and Hassan.

In the Shimoga District it is found:—

Near Saulonga, Kudli and Hoskoppa in the Honnali Taluk.

Near Kavaledurga in the Tirthahalli Taluk and near Benkipur.

In the Chitaldrug District near Lokadalalu and Audanur in the Holalkere Taluk.

In the Tumkur District on a ridge close to Kadehalli, Turuvekere Taluk. Less altered parts of this are a rather hard rock (amphibolite) which takes a fine black polish and has been largely used in the Palace at Mysore and at Tippu Sultan's Tomb, Seringapatam.

In the Mysore District—near Chattanhalli, Talur and Kadakola in the Mysore Taluk—at Manhalli in the Heggaddevankote Taluk and at numerous other places of minor importance.

Fire Clay.

No deposits of what can be properly called fire clay are known to exist, but some of the decomposed pegmatites, granites and gneisses—which

now consist largely of quartz and kaolin—and some of the more or less impure masses of kaolin and lithomarge would no doubt yield fire bricks of fairly refractory quality. Bricks of this character have been made at the City Brick and Tile Works, Bangalore, from decomposed pegmatite veins in the gneiss near Golhalli. This decomposed material contains about 30% of kaolin the remainder being quartz and sundry impurities. If care is taken to select material fairly free from iron, a good firm fire brick can be obtained by the addition of a small proportion of more plastic clay. In many parts of the State, materials of this character can be obtained from which local demands could be supplied. The material is not sufficiently valuable to stand long transport, but several small brick and tile works are in existence or projected and in most cases it should be possible to obtain some kaolinic or lithomargic material within a reasonable distance of the work. Local demands are not likely to be large and any export to surrounding areas would depend on the quality of brick which can be produced—a matter which requires further practical investigation. A number of localities in which various grades of kaolinic material have been noted will be found in the section on kaolin.

(c) Mineral Pigments.

OCHRES, OXIDES, AND COLOURED CLAYS.

The ochres are composed largely of hydrated oxides of iron mixed with more or less clayey or gritty material. They may occur as fine sediments deposited by water or as the residual products of schists, iron ores or limestones which have been subjected to long continued weathering and chemical alteration.

In colour they present various shades of yellow, brown and red and usually require to be ground finely or crushed and levigated with water so as to produce an extremely fine textured material of uniform colour which can be used for colour washes, distempers or oil paints.

Ochres of sorts occur in many places in Mysore more particularly among the iron ores, manganese ores and limestones of the Chitaldrug Schists.

Recently some prospecting licenses have been taken out in the neighbourhood of Chik Kittadhalli and Kenkere and some large samples have been taken out for experimental treatment with a view to testing the markets.

The Mysore ochres though fine in texture, when levigated, and of good body are generally dull in colour. Small quantities of fairly good yellow and red have been found, but they are usually much mixed with other material which would render clean extraction difficult and expensive. Large quantities of the duller colours can doubtless be obtained—chiefly a rather brownish-green yellow, various shades of brown or umber and dull brick red or terra cotta. If burnt the yellow material yields a pleasing reddish-brown oxide. The materials at present under investigation are disadvantageously situated owing to distance from a railway and a lack of a

convenient supply of water for washing in both of which respects improvements might be made if the products were found to be marketable. A further difficulty which has to be faced is the question of packing. If the material could be sent away in the raw state, this difficulty would not arise, but if prepared and in a very fine state it is generally required to be packed in kegs or casks which would be difficult to procure in Mysore and expensive. Possibly double bags might be used.

So far it has not been possible to ascertain very definitely the probable market values of the materials and the only way to get at this will be to prepare fairly large quantities and place them on the market.

Samples have been sent to Bombay and were not very favourably reported on. In normal times the prices in Bombay would seem to run from Rs. 2 to Rs. 4 per cwt. packed. At the present time the prices might be up to Rs. 4 to 6, but it is doubtful if there would be much demand for dull colours.

Samples sent to England are said to be worth from £3 to £5 per ton in normal times, but no very strong demand. Even at the higher price it is not likely that they could be exported at a profit.

On the other hand there is some local demand in Mysore both for the dry powder and mixed with oil as paint and the local prices are likely to be considerably higher than those quoted above. There is also some demand in Madras at prices which are stated to vary from Rs. 5 to Rs. 7 per cwt. in normal times and up to Rs. 15 at the present time.

The fact that prices are now high makes a favourable opportunity for the experimental production of large samples in order to obtain more precise information as to costs and market requirements and values and work on these lines is being proceeded with by the present licensees.

(d) Materials used for Agriculture, Chemical Industries and Food.

Many minerals are used for the preparation of manures and fertilizers and for the preparation of various chemicals used in industrial processes. Brief notes on a few of these are given below and the list might be largely extended. The notes are meant to be suggestive and to show the relative value of various factors which determine whether certain materials can be used or manufactured commercially at a profit. The estimates of cost, etc., are of a very general character and must be varied to suit specific cases and on many points rough assumptions have had to be made owing to lack of more precise information.

Proposals are constantly being put forward for the establishment of small chemical industries based on the fact that some of the raw materials exist in Mysore. It will be seen however that the raw materials often form a relatively unimportant part of the total cost of production and marketing and this is more particularly so in the case of small industries. Where the output is small the charges for supervision, interest, depreciation, etc., are relatively large. When the output is large these overhead charges diminish considerably and small advantages or reductions in cost of the raw materials begin to make themselves felt. It must not be forgotten also that many of the materials used in the production of chemicals and chemical products are themselves bye-products of other industries and that in the absence of any supply of, or demand for, bye-products work could not be carried on profitably however feasible it might be from a technical point of view.

PYRITES.

Iron Pyrites is a yellow mineral of the composition $Fe\ S_2$,

containing 46·6% of iron and 53·4% of sulphur, and is widely distributed in the rocks of Mysore in grains and crystals. The quantities present are usually very small, but in some of the chloritic and talcose schists of Chitaldrug and Shimoga and in some of the auriferous veins and lodes the proportion of pyrites present rises to noticeable amounts which may vary from 5% to 20% of the rock. Nothing in the shape of a high grade deposit containing 50% or more of pyrites has been found and, from a commercial point of view, the mineral would not deserve notice here were it not for the suggestions which have been so frequently put forward that Mysore contains valuable deposits which might be used for the local manufacture of sulphuric acid.

Amongst the most noticeable deposits which have been found are some bands or zones of veined schist amongst the old workings at Honnehatti and the quartzose ore of the Jalagargundi Mine. These have been described in the section on gold (pp. 48 and 50). In the former the zones carrying pyrites are small and very patchy and the mineral is mixed with copper pyrites and blende. In the case of Jalagargundi there is a wide lode richly studded with variable amounts of clean iron pyrites and for the sake of illustration a test was made with a picked sample of the richer portions. The sample was crushed and concentrated and the pyritic concentrate was found to amount to 20% of the rock and to contain 46% of sulphur. These richer portions could not be mined separately and the average contents of the lode would probably lie between 5% and 10% of pyrites.

For the sake of example we may take the favourable view that a considerable amount of material containing 10% of pyrites could be mined at reasonable cost. As the output would be small, it would be a low estimate to put the cost of mining, crushing and concentrating the rock at Rs. 10 per ton and, as 10 tons of rock would be required for 1 ton of pyrites, the pyrites would cost Rs. 100 per ton at the mine.

We may now consider how much a sulphuric acid works

could afford to pay for pyrites. It should be possible to deliver Spanish Pyrites at a works in Mysore for some Rs. 50 to 60 per ton and to deliver Sicilian Sulphur at Rs. 100 per ton or less and Japanese Sulphur at a still lower figure. Of these materials sulphur would be more economical than pyrites.

If therefore we can get sulphur at Rs. 100 or less, the relative value of the Mysore pyrites (containing 46% of sulphur) would be Rs. 46 per ton or less. As, according to the above example, it costs Rs. 100 at the mine, the proposition is not commercially feasible. Even if we could find an ore containing 20% of pyrites, it still would not pay in competition with imported sulphur.

The only hope of being able to use Mysore pyrites would be the development of a gold mine in which the pyrites would be obtained as a bye-product and could be sold cheaply and this is not without the bounds of possibility, though its advent is not at present in sight.

SULPHURIC ACID.

Cheap sulphuric acid is an extremely important factor in many chemical industries and the desirability of manufacturing it in Mysore has often been discussed and advocated. We have shown that local supplies of pyrites are out of the question, at any rate at present, in comparison with imported sulphur.

The problem of producing sulphuric acid in Mysore more cheaply than it can be imported depends entirely on the local demand for it. The extent of this demand is not very accurately known, but Bangalore probably imports 100 to 150 tons of concentrated acid a year and there may be a small additional import to other places. It is probable that the total demand does not exceed half a ton per day on the average.

How far it would be technically feasible to erect and work a plant to produce only half a ton a day is doubtful and the profit to be obtained, if there was a profit, could not amount to very much.

We may more usefully consider the case of a small unit to make 4 to 5 tons a day of concentrated acid. This would be capable of turning out about 1,900 tons of chamber acid, or 1,200 tons of concentrated acid per year, or partly one and partly the other.

Plant and erection would cost about one lakh, buildings and bungalows half a lakh or so and half a lakh for sundries and working capital. On this we might allow a depreciation of 15% on the plant, 5% on buildings and 5% interest on the total.

Supervision, office, laboratory and labour might be put at Rs. 3,500 per month of which skilled supervision forms the greater part and would be independent of the quantity produced within wide limits.

Materials required per ton of chamber acid would be as follows:—

	Rs.	a.	p.
4½ cwts. sulphur at Rs. 5	22	8	0
3 cwts. coal at Re. 1	3	0	0
Nitric acid and sundries	9	8	0
Total ...	35	0	0
For one ton of concentrated acid we require.—			
1·6 tons chamber acid at Rs. 35 ...	56	0	0
4 cwts. English coke at Rs. 40 per ton ...	8	0	0
Sundries	4	0	0
Total ...	68	0	0

TABLE 22.—*Approximate estimates of cost of sulphuric acid.*

	tons per year		
Chamber acid	1,900		
	Rs.	a.	p.
Materials	35	0	0
Supervision and labour	22	0	0
Depreciation	9	0	0
Interest	5	0	0
Total per ton ...	71	0	0
Concentrated acid.—			
Materials	68	0	0
Supervision and labour	35	0	0
Depreciation	15	8	0
Interest	8	8	0
Total per ton ...	127	0	0

One anna per lb. is Rs. 140 per ton and the above rough estimates appear to show that chamber acid could be made here for ½ an anna per lb. and concentrated acid for a little over ¾ anna per lb.

Concentrated acid can be imported into Bangalore, packed in jars, at something between 1½ and 2 annas per lb. so that for sale or use in Mysore the locally made acid should have a fair margin in its favour. The figures depend entirely on the quantity, *viz.*, about 1,200 tons per year, and as the present demand probably does not exceed 150 tons there is a long way to go before these favourable conditions can be realized.

If the plant worked part time so as to produce only 150 to 200 tons a year, the cost would go up to about 2 annas a lb. or perhaps more. If a less costly plant was feasible and the staff could be employed on other chemical work for part time, the cost might come down to something between 1 and 2 annas a lb. and the profits, if any, would be small.

Further uses for sulphuric acid may be developed and if the output rises to several tons per day it can be manufactured locally more cheaply than it can be imported. The essential question in each case will be whether the article to be manufactured can stand a charge of even ¾ anna per lb. for sulphuric acid or whether it would not be more cheaply manufactured by transporting the other ingredients or materials to Madras or elsewhere where the acid could be made still more cheaply in larger quantities. Each case has to be considered on its individual merits and the following may be taken as an illustration.

EPSOM SALT.

There is a certain demand for crude Epsom Salt in India part of which is satisfied by manufacture in India. Pre-war prices have been quoted at Rs. 3 to 4 per cwt. in Bombay and up to Rs. 6 or 7 in Madras. At present (1916) prices may be from Rs. 10 to 13 per cwt.

It has been suggested that the Mysore magnesite should be utilized and some excellent samples of Epsom Salt have been prepared in the Chemistry Department of the Indian Institute of Science, Bangalore.

The commercial aspect may be roughly summarized as follows:—

Epsom Salt ($MgSO_4$, 7 H_2O) contains about 16½ per cent of magnesia (MgO) and the Mysore magnesite contains about 45 per cent of magnesia.

One cwt. of Epsom Salt requires approximately:—

42 lbs. of magnesite.

47 lbs. sulphuric acid.

The cost of these materials in Bangalore may be put at:—

42 lbs. magnesite at Rs. 15 per ton=4½ annas.

47 lbs. sulphuric acid at 1½ to 2 as. per lb.=Rs. 4-4-0 to Rs. 6.

The raw materials amount therefore to from Rs. 4-8-0 to Rs. 6-4-0 per cwt. of Salt and the latter figure or higher

would apply at the present time. These figures more or less correspond to the quoted sale values in normal times and leave little or nothing for costs of manufacture, transport and profit.

Another useful way to consider the matter is to compare the effect of taking the magnesite to Bombay or Madras and doing the work there. This would add some 4 to 12 annas to the cost of the magnesite, but the sulphuric acid would probably be reduced to ½ or ¾ anna per lb. and the total cost of raw materials would be 2 or 3 rupees less per cwt. of Salt than in Mysore and competition seems out of the question.

It has been suggested that makers of aerated waters might use magnesite instead of sodium carbonate, with sulphuric acid, for producing carbonic acid and sell the resulting Epsom Salt as a bye-product. They may be prepared to consider this, as the value of the Epsom Salt would largely pay for the sulphuric acid while the increased cost of manufacture would be offset by the saving in cost of magnesite as compared with sodium carbonate.

If local demand and production of sulphuric acid can be developed so as to bring its cost down to about ½ an anna per lb., the position would be materially altered.

LIME.

Lime is said to be required by many of the Mysore soils and a note on the prospects of obtaining crushed limestone or burnt lime for agricultural purposes will be found in the Section on Limestone. (pp. 177 and 181.)

The mineral *Apatite*, which is a phosphate of lime, is much sought after as a source of superphosphate for agricultural use for which purpose it is collected and treated with sulphuric acid which decomposes it into gypsum and calcium superphosphate. It occurs as an accessory mineral in many rocks, but no commercially valuable occurrence has been located in Mysore. About 5 miles east of Channarayapatna, Hassan District, a small vein, about 9 inches thick, of the mineral was

found many years ago, but the quantity was insignificant and no further supplies have been found.

Large quantities of lime are now being used in America and Europe for the production of calcium carbide and calcium cyanamide. The latter, which in its commercial form is called "nitrolim" or "lime-nitrogen", is used directly as a fertilizer and might prove of considerable use in Mysore where the soil is deficient in lime. Dr. Coleman, Director of Agriculture, and Mr. H. V. Krishnayya, Chemist to the Departments of Geology and Agriculture, have been making enquiries and experiments on this point and the possibility of obtaining the materials and making the cyanamide in Mysore has been referred to this Department for opinion.

The following note has been prepared on the scanty information available here and further enquiries are being made.

Calcium Cyanamide.

For many years the world has been supplied with enormous quantities of sodium nitrate from the celebrated deposits in Chile. This material is valued mainly on account of its nitrogen and is used largely as a fertilizer as well as for the production of nitric acid and ammonia. It is recognised that the deposits are by no means inexhaustible and that with the increasing demand for fertilizers for agricultural purposes the supply of nitrogen from this source cannot be expected to last for many years. Much attention has therefore been paid to the artificial production of compounds containing nitrogen in a form suitable for agricultural purposes and of these the principal source, which is an increasing one, is the utilization of the ammonia which is produced as a bye-product during the distillation of coal for the production of gas and coke. The ammonia is converted by the aid of cheap sulphuric acid to ammonium sulphate in which form it is used as a fertilizer.

Fixation of atmosphere nitrogen.

In recent years numerous, more or less successful, attempts have been made to extract nitrogen from the atmosphere in which it exists in

practically unlimited quantities, and to fix it in combination with other elements in a form suitable for distribution and use as a fertilizer. Two main types of processes are employed, *viz.*:—

(1) The direct combustion of the nitrogen and oxygen of the atmosphere in the electric arc which results in the formation of various oxides of nitrogen which are converted subsequently into nitric acid; and

(2) The combination of the nitrogen of the air with metals or carbides of which one of the most important products is *Calcium Cyanamide.*

Of the first group or arc processes it is not necessary to say anything here. The efficiency of these processes is stated to be very low and relatively large amounts of very cheap electric power are required. Under present conditions it would seem that they can be conducted on a commercial basis only in places such as Norway where abnormally cheap power can be obtained in large quantity. The comparatively high rates obtainable in Mysore, even under the most favourable conditions, would seem to create an insuperable bar to the adoption of any such processes here.

In the case of the cyanamide process the amount of power required is very much less, per unit of nitrogen combined, than in the arc processes and a higher rate for power is permissible. It may be worth while therefore to discuss briefly the general features of this process under conditions which may be expected to obtain in Mysore.

Carbide.

The process may be outlined as follows, but the reactions are by no means as simple as the equations given would seem to suggest. A mixture of burnt lime and coke is heated in electric furnaces with the production of *Calcium Carbide.*

$$\underset{\text{(lime)}}{CaO} + \underset{\text{(carbon)}}{3C} = \underset{\text{(carbide)}}{CaC_2} + CO$$

Cyanamide.

The carbide is very finely ground—an operation which is attended with considerable risk of explosion—and is brought into contact with

nitrogen obtained from liquid air. The reaction takes place in small retorts and the product is ***Calcium Cyanamide***, or "nitrolim" as it is sometimes called. The reaction may be outlined thus:—

$$\underset{}{CaC_2} + 2N = \underset{\text{(cyanamide)}}{CaCN_2} + \underset{\text{(graphite)}}{C}$$

A number of other reactions take place and the commercial cyanamide or nitrolim is said to contain 57 to 63 per cent cyanamide; 14 per cent graphite; 20 per cent lime and 7 to 8 per cent silica and oxides of iron and aluminium. The total nitrogen content is 20 to 22 per cent.

The Cyanamide is ground and treated in various ways and placed on the market as a fertilizer.

Ammonia.

Ammonia can be produced at a small additional cost, by subjecting wet Cyanamide to heat and pressure thus:—

$$CaCN_2 + 3H_2O = \underset{\text{(ammonia)}}{2NH_3} + CaCO_3$$

Value.

Cyanamide for fertilizing purposes is quoted in Madras at about Rs. 180 per ton and we may now consider, with such general information as we have at our disposal, whether there is any prospect of commercial production in Mysore and the main controlling factors and points on which further information is required.

Raw Materials.

It is stated that very high grade carbide is required and this means the use of high grade lime and coke. As pointed out in another section, we know of no high grade limestone in Mysore and it is not known whether the lime which we could produce—containing about 85 per cent of CaO—could be economically used or whether the resulting carbide would nitrify satisfactorily. It would, at any rate, be less economical than a purer material and the final cost per unit of nitrogen fixed would rise accordingly. The next point is the supply of carbon. We have no coal or coke in Mysore and Indian coke

would be expensive and impure. On the other hand we have charcoal, the purity of which is very high, but it is not known if it could be used for making carbide. We believe that charcoal has not been used hitherto, but it is probable that a suitable process and furnace could be devised.

Power required.

The most important factor of cost is that of electric power and it is stated that Cyanamide cannot compete in Europe with other nitrogen fertilizers if the power costs more than £3 per H. P. year. In Mysore power costs about £10 per H. P. year, but it is possible that in future some surplus power may be available at much cheaper rates in the neighbourhood of the generating stations. We understand that about $\frac{3}{4}$ of a H. P. year is required for the production of a ton of carbide and a total of about $\frac{1}{2}$ a H. P. year, or 3,267 K. W. hours, for a ton of Cyanamide. For the purpose of a rough estimate we assume that about $\frac{2}{3}$ of a ton of lime and $\frac{1}{2}$ a ton of charcoal will be required per ton of Cyanamide.

Materials and power would be as follows :—

	Rs.
3,267 K. W. hours at 0·2 annas per unit ...	41
electrodes	10
$\frac{2}{3}$ ton of lime at Rs. 21	14
$\frac{1}{2}$ ton of charcoal at Rs. 25	12·5
Total ...	77·5

If power was available at 0·1 anna per unit this total would reduce to Rs. 57 and these figures show clearly the supreme importance of the power charges.

Cost of Production.

A plant to produce 10,000 tons a year would require 5,000 H. P. and though we have little information to go on we may assume some figures for other essential items and frame the following tentative estimate.

TABLE 23.—*Rough estimate of cost per ton of Cyanamide.*

	Rs.
Power	20·5 to 41
Materials	36·5
Labour	20
Supervision and Management	5
Interest and depreciation	15
Repairs, sundries, etc.	10
Total ...	107 to 127·5

If the value of imported Cyanamide remains at anything like Rs. 180 a ton it looks as if there might be some chance for a local production if the cost of power can be kept within the limits indicated. We must remember however that owing to the impurities in the limestone the resulting product will be lower in nitrogen and less valuable than the imported article, perhaps 20 to 25 per cent lower, and that we have still to find out whether it is possible to make a saleable product at all with the materials at our disposal. The subject is at any rate worth attention and even if our lime should prove quite unsuitable for this purpose the cost of lime is such a small item that it might be possible and even advantageous to import a high class lime for the purpose.

EARTH SALT AND EARTH SODA.

Salt.

An impure salt is prepared in many parts of the State from the saline alluvium and soils which are found along water courses and in tank beds, chiefly in the gneissic country. These saline materials occur in many parts of the State and chiefly along the course of the Vedavati river and its tributaries in the Chitaldrug and Tumkur Districts and along the Mugur river in the Gundlupet Taluk of the Mysore District.

The salt earth is collected chiefly during the dry months of the year between January and April and is lixiviated with water in wooden tubs or vats. The brine is run off into shallow pans in which the salt crystallizes out as the water is evaporated by the sun.

The salt finds a local market and is usually fairly impure containing variable amounts of soda, lime, magnesia and clay or sand. The production is variable and usually small and probably does not exceed a few hundred tons in a year. The price varies according to quality from about Rs. 2 to Rs. 10 per cwt., the average being about Rs. 3 or 4.

Soda.

In some places there is a saline efflorescence which is distinctly alkaline owing to the presence of sodium carbonate. The principal localities are in the neighbourhood of Mandya and in the Taluks of Hosdurga, Hiriyur and Challakere. The best material occurs as a thin white efflorescence which appears on low lying ground which has been saturated or water-logged during the rainy season. The surface layer carrying the efflorescence is scraped off during the months of January and February and may contain from 5 to 12 per cent of sodium carbonate with varying amounts of sodium chloride, the remainder being sand. This material is known as *dhoby's* earth and is used for washing clothes. Some years ago this earth used to be lixiviated with water and the solution evaporated in shallow pans made of clay or chunam smoothed over with cow-dung. Successive solutions were poured into the pan and evaporated until a cake, about ½ an inch thick, was formed. This was then broken up and sold as soda cake. For some years past the production of soda cake in Mysore has been abandoned, but considerable quantities are imported from the Anantapur District. A sample of this cake (*Vide* Table 24, No. 1) gave about 40 per cent of sodium carbonate and 20 per cent of salt and is fairly impure.

The cake is said to be worth Rs. 2-2-0 to 2-4-0 per cwt. at Penukonda and Rs. 4-0-0 to 4-8-0 in Bangalore. The

increase in price for Bangalore seems very high even allowing for packing and transport and it is difficult to understand why it should command such a high price when good imported soda ash can be obtained for about Rs. 5 per cwt.

A number of samples of the earth have been collected departmentally from the Mandya area and these are being experimented with in the Chemistry Department of the Indian Institute of Science. A number of analyses kindly furnished by the Institute are given in Table 24 and the following information about them may be of interest.

Numbers 2 and 3 were collected from small areas in the month of December and represents the fresh incrustation after the previous rains. In collecting it some sand is necessarily taken up and samples show from 6½ to 12 per cent of sodium carbonate ($Na_2 CO_3$) with remarkably little salt ($NaCl$). This result was interesting and encouraging and further samples were obtained from a much wider area, during March, most of which have not been dealt with yet.

Numbers 4 to 7 form a series from one place by taking off successive layers of material. It will be seen that the bulk of the soda is in the top layer, one inch thick, and that there is considerable concentration in the topmost crust which averages about ⅛th of an inch in thickness.

It is noteworthy that the relative proportion of salt has greatly increased in comparison with samples 2 and 3. The significance of this has not been determined, but it is stated that the top soda-bearing layer had already been removed once, earlier in the year, and that there is a tendency for the subsequently formed incrustation or efflorescence to contain relatively more salt. In fact there are a number of salt pans in the area and the earth or sand is used for production of salt after the top layer has been removed for use as earth-soda.

Sample No. 8 represents about 2 tons of surface scrapings collected during March. It is possible that had the samples been collected earlier in the season the proportion of salt would have been lower.

TABLE 24—*Analyses of Alkaline Earth.*

Serial No.	Registered number	Na_2CO_3 per cent	NaCl per cent	Insoluble per cent	Organic per cent	Moisture per cent	Remarks
1	O/1045	40·40	19·70	20·50	1·50	17·50	Soda cake from Penukonda.
2	X /524	6·57	0·51	90·00	0·18	2·65	Surface incrustation about ¼ to ½ inch thick from Chinnanhalli near Mandya.
3	X/525	11·75	0·43	83·00	0·29	3·75	Surface incrustation about ¼ to ½ inch thick from Punakanhalli near Mandya.
4	$R_2/4$	12·0	15·2	...	...	...	Surface crust ½ inch thick. Field near Mandya.
5	$R_2/5$	4·7	3·0	...	...	...	Next layer below, ½ inch thick. Field near Mandya.
6	$R_2/6$	0·26	0·22	...	...	...	Next layer below, 2 inches thick. Field near Mandya.
7	$R_2/7$	0·14	0·02	...	...	...	Next layer below, 2 inches thick. Field near Mandya.
8	$R_2/20$	5·46	2·62	...	...	...	Surface scrapings ½ to 1 inch thick. General sample from a number of localities round Mandya. Samples 2 and 3 collected about middle of December. Samples 4 to 8 collected about middle of March.

There is evidently room for much further enquiry as to the conditions of occurrence and the composition. In the meantime advantage will be taken of the facilities afforded by the Institute of Science to have a bulk test made of the product obtainable from No. 8.

It has not been possible to obtain any reliable information as to the amount of alkaline earth annually available. In a few places from 100 to 200 cart loads are said to be removed per annum and altogether the Mandya area might yield one or two hundred tons of the earth a year. If we take an average recovery of 5 per cent of sodium carbonate the latter would amount to some 5 to 10 tons. This is at present a mere guess, but it is hoped to get further information. The chief difficulty to be faced will be the proper collection of material and the expense of carting small lots from a radius of several miles and we cannot say at present whether these will prove prohibitive features.

III. Materials for Construction, etc.

LIME KANKAR.

Lime kankar is a concretionary form of carbonate of lime ($CaCO_3$) and occurs in the form of irregular nodules or nodular veins on the weathered surface of gneiss or schist and in joints and fissures to a depth of several feet. As a rule, it is not associated with limestone, but a case has been reported from Voblapur where the surface of a limestone bed has been converted into a sort of porous kankar. Ordinarily it appears to owe its origin to the weathering of gneiss or schistose traps whereby the lime silicates are broken up and the lime taken into solution by carbonated waters from which the carbonate of lime separates out at or near surface in nodular concretionary forms. As might be expected the kankar is usually impure and contains included sand and gravel. When excavated and picked out in large quantities the quality of the kankar depends very much on the care with which the nodules are sorted from decomposed rock and soil and the grade of the material is very variable and usually much below that of carefully selected samples.

The material is very widely distributed and may be found in most taluks where it is collected and burnt in small pot kilns and used locally for whitewashing, mortar, etc. Various analyses are given in Table 25 and referred to below by their serial numbers. In some places large quantities have been obtained and exported. Of these some of the principal are in the Mandya Taluk. From Sindlagiri (No. 1) it is reported that 50 or 60 waggons used to be railed to Bangalore every month and also considerable quantities from the banks of the Hebhalla. The kankar was mostly of poor quality and the supply of good material now available is said to be small and

Table 25.—*Analyses of kankar from the Mysore State and from Salem (Madras Presidency).*

Serial No.	Registered No.	Moisture %	Loss on ignition %	Insoluble residue %	SiO_2 %	SiO_2 soluble %	Fe_2O_3 %	Al_2O_3 %	MnO %	CaO %	MgO %	S %	P %	Locality
1	O—210	...	32·00	...	24·78	...	1·56	4·47	...	25·90	10·46	0·048	0·004	Sindlagiri, Mandya Taluk.
2	R- 172	0·67	36·82	...	9·08	...	2·35	1·06	0·10	45·85	4·12	0·036	0·006	
3	R—173	0·90	35·55	...	10·98	...	2·53	2·43	0·074	43·82	3·50	0·034	0·008	
4	O—208	...	41·94	...	4·58	...	0·96	1·51	Trace	45·60	6·38	0·039	0·002	
5	O—209	...	42·26	...	2·70	...	0·65	0·76	Trace	52·70	1·17	0·036	0·005	
6	C—46	0·755	CO_2=37·806 H_2O=1·880	6·67	...	...	2·93	...	...	49·13	Trace	...	...	
7	O—620	0·70	36·39	4·96	...	3·32	3·18	..	...	48·30	0·99	...	...	Vicinity of Kannambadi, Krishnarajpete Taluk.
8	O—621	0·39	38·11	9·45	...	3·57	5·46	...	...	36·69	6·08	...	...	Do
9	O—622	0·42	36·39	6·84	...	3·07	4·29	...	...	44·73	3·44	...	...	Do
10	O—623	0·44	36·40	10·06	...	3·63	4·11	...	...	40·69	4·50	...	...	Do
11	O—624	0·64	34·11	12·17	...	5·12	6·60	...	...	41·26	0·96	...	...	Do
12	O—625	0·67	38·21	6·57	...	3·16	3·15	...	...	46·96	1·30	...	...	Do
13	X—463	...	CO_2=3·50	16·13	...	...	4·60	...	...	65·00	0·85	...	...	Birur, (burnt kankar).

much of the kankar used in Bangalore is said to be obtained from the Salem District (Nos. 2 and 3). Small quantities of superior kankar are obtained from Mardevanhalli and Malchakanhalli in the Mandya Taluk (Nos. 4 and 5) and are used for chunam. Other places where fairly large quantities are obtained are Honnali, Birur, Hiriyur, Hole-Narsipur and various parts of the Hunsur and Gundlupet Taluks. A large deposit was found close to the site of the Marikanave dam from which the whole of the lime required for the dam was obtained (No. 6) and at the present time large quantities are being obtained within a radius of 12 miles from the Kannambadi dam and used in its construction (Nos. 7 to 12). The analyses given in Table 25 show that the material is very variable in composition and it is improbable that the burnt kankar will contain more than about 65 per cent of lime (CaO) on the average and in many cases much less. No. 13 is an analysis of burnt kankar from Birur. The clayey and sandy impurities are not altogether useless as they serve to impart a certain amount of hydraulicity to the lime, but they increase the collection and burning charges per unit of lime. The chief defect of kankar is its great variability and though this may not be of much moment in mortar or surki-mortar used for ordinary building purposes it would be very detrimental for high class structural work, ferro-concrete or the production of a cement of any standard quality.

Cost of burnt lime.

The cost of lime burnt from kankar depends very largely on the cost of collecting and sorting the kankar and the cost of fuel. Table 26 gives the cost of kankar at various points.

The cost of casuarina charcoal at Bangalore is Rs. 30 per ton.

The cost of ordinary charcoal at Kannambadi is Rs. 30 per ton.

The cost of ordinary charcoal at Marikanave is Rs. 15-5 per ton.

The cost of ordinary charcoal chips and cowdung at Birur is about Rs. 20 per ton.

TABLE 26.—*Cost of kankar per ton.*

Locality of deposit	Cost delivered at Railway Station	Loading and rail charges to Bangalore	Unloading and carting to kilns	Total
	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.
Maddur ...	1 13 4	1 12 0	0 9 4	4 2 8
Mandya ...	1 10 8	2 1 4	0 9 4	4 5 4
Morappur and Samalpatti (Salem).	1 4 0	2 3 5	0 9 2	4 0 7
Marikanave ...	...	...	...	1 4 6
Kannambadi ...	...	...	...	2 8 0 to 3 0 0
Birur ...	...	...	...	4 0 0

Table 27 gives the approximate costs of burnt lime per ton, but reliable figures are difficult to obtain.

TABLE 27.—*Cost of burnt lime per ton.*

	Bangalore		Marikanave	Kannambadi	Birur
	Quantity	Cost	Cost	Cost	Cost
	Tons. cwts	Rs. a. p.	Rs. a. p.	Rs. a. p.	Rs. a. p.
Kankar ...	1 10	6 4 6	1 7 0	3 14 0	5 0 0
Fuel ...	0 3¾	5 10 0	3 12 0	9 4 0	5 0 0
Charges for burning.	......	1 10 7	1 5 0	1 6 6	1 14 0
Upkeep of kiln	......	0 6 8	......	......	......
Total ...	......	13 15 9	6 8 0	14 8 6	11 14 0

These figures are given for the purpose of discussing in the next section whether it is possible to replace any of this material by lime burnt from limestone. For local use and in special cases where kankar and fuel are available close at hand as at Marikanave it is not likely to be possible to furnish an

equally cheap substitute. In other cases it will be largely a question of the extent of the demand and the suitability of the product for the purpose required. It must be remembered that the lime burnt from kankar is very variable and contains a large proportion of impurity and that for many purposes it would be advantageous to pay somewhat more for a uniform material richer in quick-lime.

LIMESTONE.

Distribution.

A large number of bands of limestone have been located the distribution of which is shown on the map and the composition of various specimens and samples is given in Tables 28 and 29. In referring to these the serial number of the analysis will be given in brackets. Starting from the north there are some bands running E and W to the north of Honnali of which we have no analyses.

To the north of Kumsi there are several bands of magnesian limestone which are much gashed and veined with quartz. A large amount could be obtained by sorting and dressing which would be low in silica (No. 1), but probably not so low on the average as the specimen analysed. Somewhat similar material occurs on the north spur of Shankargudda (No. 2). Near Bikonhalli, north of Shimoga, there are large masses of very siliceous magnesian limestone (No. 3) and in the schists between Channagiri and Tarikere there are many outcrops of similar material (Nos. 4 to 8). In this area the limestones are often interbanded with chlorite schist and amongst them are comparatively small patches of purer non-magnesian limestone such as that represented by (No. 9).

From here we may pass east to the western side of the Chitaldrug schist belt in which a very extensive series of limestone bands occur from the neighbourhood of the Marikanave lake and continue southwards past Huliyar, Chiknayakanhalli and Dodguni. As will be seen from the analyses these bands consist of various calcium and magnesian limestones some of which are fairly low in silica.

Further to the south we get one or two small patches of magnesian limestone at Kannambadi (Nos. 16 and 17), a large band of magnesian limestone to the west of Chettanhalli (No. 18) and another 12 miles south of Sargur—all in the Mysore District.

The origin of the limestones is doubtful. It has been suggested that many of them are not of sedimentary origin nor aqueous precipitates but due to intense calcification of trap and schist (*vide* Bulletin No. 6).

Composition and character.

The analyses given in Table 28 show the composition of various specimens collected during the course of survey work and those in Table 29 show the composition of larger samples taken in certain areas. Broadly speaking these limestones fall into two classes according to whether they contain much or little magnesia. The dividing line between these two classes is usually taken at 5 per cent of MgO in the burnt lime or from 2½ to 3 per cent in the raw limestone. Those with less than these amounts are classed as "high-calcium" and those with more as "magnesian" limes or limestones. In Mysore by far the larger part of the limestone is magnesian with about 15 per cent of MgO and varying between 10 per cent and 18 per cent and these might be classed as *Dolomite* with variable amounts of silica and other impurities. For convenience we will refer to them as dolomite and retain the word limestone for rocks containing less than about 3 per cent of MgO. From the analysis it will be seen that the two classes are fairly sharply separated and that varieties with intermediate amounts of MgO have not been found so far.

Unfortunately the two classes of rock do not appear to occur in well defined beds and do not present much difference in aspect with the result that chemical analysis is usually necessary to distinguish them.

In the Voblapur area, where a large number of samples have been collected, the two varieties occur in somewhat irregular zones or patches of considerable extent and it should be

possible to obtain large quantities of either variety at will. The limestone of this area is represented by analyses 23 to 28 containing an average of about 50 per cent CaO and 7 per cent insoluble residue. Of the latter about 5 per cent is SiO_2.

The dolomite is represented by analyses 29 to 32 and the greater part of it contains less than 2 per cent insoluble residue, about 46 per cent of $CaO+MgO$ and 5 per cent $Fe_2O_3+Al_2O_3$ and should be very suitable as a furnace flux. In the southern extension of this area near Dodguni the varieties are more mixed and often siliceous and the high-calcium limestones, as represented by analyses 13 and 34, are in comparatively small patches the mining of which would be possible only for moderate quantities of high class material for special purposes.

The material from the Huliyar area (19 to 22) does not appear to be so good as that from Voblapur. The rock from the Channagiri-Tarikere schists and from Bikonhalli is mostly very siliceous dolomite (3 to 8). It is mostly fine grained with the quartz and silicates intimately distributed through the mass and some of it might possibly be suitable as a natural cement rock. This has not been tested and success seems very doubtful owing to variation in composition and to the large number of granules and veinlets of quartz which are clearly perceptible under the microscope.

In many areas the limestones are much mixed with shreds of quartz and schist and also veined with quartz and the material is practically useless as a source of lime. Some of the dolomitic bands to the north of Kumsi are much gashed or veined with quartz, but the veins are of sufficient size and definiteness to permit of being hand picked if it was found necessary to use the dolomite as a flux in that area.

On the whole the materials from the Voblapur area, which is within about 12 miles of the railway, appear to be the most promising for the production of either limestone or dolomite in large quantities.

So far as tested at present, these materials possess the

TABLE 28—*Analyses of Mysore Limestones—chiefly specimens.*

Serial No.	Registered number	Loss on ignition	Insoluble residue	Soluble SiO_2	$Fe_2O_3+Al_2O_3$	CaO	MgO	Locality	Remarks
1	S_2/770	...	1·01	...	9·36	30·49	15·09	North of Kumsi, Kumsi Sub-Taluk	
2	H_5/297	...	6·35	...	4·62	29·04	15·92	Shankargudda, Shimoga Taluk	
3	A/908	...	24·75	...	3·66	23·27	13·78	Bikanhalli, ,, ,,	
4	J_4/71	...	19·87	...	4·38	24·12	15·52	Joldhal, Channagiri ,,	
5	J_4/186	...	22·25	...	3·36	23·93	12·23	Balekal, ,, ,,	
6	J_4/212	...	17·40	...	3·32	25·12	15·60	Rangapur, Shimoga ,,	
7	J_4/230	...	15·88	...	6·20	25·46	14·11	,, ,, ,,	
8	J_3/952	...	10·27	...	5·54	27·00	15·96	Tarikere, Tarikere ,,	
9	J_4/68	...	5·19	...	2·16	48·92	2·16	4 miles E. N. E. of Joldhal, Channagiri Taluk.	

TABLE 28—*Analyses of Mysore Limestones—chiefly specimens—concld.*

Serial No.	Regis-tered number	Loss on ignition	Insoluble residue	Soluble SiO_2	Fe_2O_3+ Al_2O_3	CaO	MgO	Locality	Remarks
10	R/117	40·62	5·49	..	1·95	47·98	2·89	Huliyar area, Chiknayaikanhalli Taluk.	
11	R/956	40·05	7·72	...	1·10	49·90	1·26	Voblapur area, Gubbi Taluk	
12	R/911	44·36	2·75	...	5·10	30·00	16·44	,, ,, ,,	
13	Z_3/345	...	0·97	...	0·76	53·84	0·96	Dodguni area, ,, ,,	
14	Z_4/896	...	3·36	...	3·85	33·00	15·99	,, ,, ,,	
15	Z_4/897	...	10·78	...	4·95	27·50	16·66	,, ,, ,,	
16	...	...	2·37	0·10	4·68	32·44	15·96	Kannambadi, Mysore ,,	
17	O/678	CO_2=0·09 H_2O=6·87	4·15	0·62	7·24	51·82	29·17	,, (Burnt lime) ,, ,,	
18	J_3/671	...	5·54	...	4·08	30·20	16·21	Chattanhalli, ,, ,,	

TABLE 29—*Analyses of samples of Mysore Limestones from certain areas.*

Serial No.	Registered number	Loss on ignition	Insoluble residue	Soluble SiO_2	$Fe_2O_3+Al_2O_3$	CaO	MgO	Locality	Remarks
19	R/930	...	9·16	0·03	1·26	46·76	2·83	Huliyar area, Chiknayakanhalli Taluk, Tumkur District.	High calcium limestones.
20	R/938	...	8·89	0·04	0·94	48·10	1·35	,,	
21	R/940	...	8·67	0·02	0·94	48·16	2·11	,,	
22	R/929	...	5·76	0·02	4·88	29·64	16·51	,,	Magnesian limestone.
23	R/957	38·16	11·86	...	1·75	46·10	1·53	Voblapur area, Gubbi Taluk, Tumkur District.	High calcium limestone.
24	R/908	40·42	7·08	...	1·40	49·60	1·25	,,	
25	R/958	41·06	6·42	...	0·85	50·65	0·99	,,	
26	R/910	41·35	5·75	...	1·10	50·70	1·16	,,	
27	R/959	42·85	2·31	...	0·85	53·00	1·19	,,	
28	R/960	40·42	7·33	...	1·60	48·80	1·54	,,	

TABLE 29—*Analyses of samples of Mysore Limestones from certain areas—concld.*

Serial No.	Registered number	Loss on ignition	Insoluble residue	Soluble SiO_2	$Fe_2O_3+Al_2O_3$	CaO	MgO	Locality	Remarks
29	R/912	42·20	7·72	...	4·60	28·90	10·45	Voblapur area, Gubbi Taluk, Tumkur District.	Magnesian limestone.
30	R/914	45·26	0·72	...	5·25	31·00	16·31	,,	
31	R/961	44·55	1·99	...	5·20	30·35	14·97	,,	
32	R/962	45·76	0·70	...	5·15	31·15	15·94	,,	
33	R/895	41·16	6·27	...	2·65	47·45	3·06	Dodguni area, Gubbi Taluk, Tumkur District.	High calcium limestone.
34	R/897	43·19	1·65	...	0·55	53·77	0·90	,,	
35	R/902	...	8·87	0·02	4·00	29·00	16·90	,,	Magnesian limestone.
36	R/964	...	3·11	0·02	4·92	28·76	18·44	,,	
37	R/965	...	5·02	0·03	3·78	28·80	18·17	,,	

defect of burning to a brown colour and do not yield a white lime. This is immaterial for some purposes such as fluxing, production of surki mortar, cement, etc., but evidently bars their use for finishing purposes, chunam, whitewash, etc. The analyses show that comparatively little iron is present, especially in the high-calcium varieties, but it is probable that an appreciable quantity of manganese is present which has not been determined.

USE OF THE LIMESTONES.

Up to the present the limestones and dolomites have not been used. All the lime hitherto used has been made from kankar as already explained and it is not difficult to account for this preference. Kankar is obtainable almost anywhere in the small quantities required for local use. It can be picked up on surface or dug out from soft material to a depth of a few feet and requires no blasting or breaking and is easily burnt in small pot or trough kilns with local fuel. Limestone on the other hand is much less widely distributed; it is a hard rock requiring much blasting and breaking and unless the quarrying and burning is done on a considerable scale with trained labour the lime would undoubtedly be more expensive than that from the local kankar.

If the limestones are to be brought into use it will be necessary to ascertain that they are suitable for various purposes and that a large and steady demand can be secured permitting of the erection at some one place of the necessary kilns, plant, tram-lines, etc., and the employment of skilled supervision and labour. The following notes are merely suggestive of the possibilities which require technical investigation. There are grounds for thinking that supplies of kankar are not as abundant nor as good in quality as they have been in the past. Petty local supplies will no doubt be available for many years, but the fact that large quantities are now imported into Bangalore and the Kolar Gold Field from Salem while the supplies from Mandya have correspondingly

diminished seems to point to exhaustion of the better class of local material. Again, it is stated that large quantities of lime will be required for the second stage of the Kannambadi dam and that the supply from the surrounding area is likely to prove insufficient and if this is so the kankar will have to be obtained from greater distances at an increased price. These facts are noted as suggesting that the time may not be far distant when we shall be obliged to draw upon our limestones for supplies of lime to large centres and large works and the desirability of investigating the possibilities of doing so.

Quarrying.

The quarrying of hard limestone in small quantities by inefficient local labour would probably cost Rs. 2 per ton or more. Public Works Department contract rates for excavation of granite are usually Rs. 2-8-0 to Rs. 3 per cubic yard solid and in some cases the rate is slightly under Rs. 2 for larger scale work. A cubic yard of solid limestone weighs about 2 tons so that the latter rate comes to Re. 1 per ton. In a properly organized quarry with good benches and no stripping this latter figure should be considerably improved upon and it will probably be ample to allow Re. 1 per ton for limestone broken and delivered at kilns close to the quarry. For 1 ton of burnt lime $1\frac{3}{4}$ tons of limestone will be required, or 2 tons allowing for loss, defective burning, etc. This means Rs. 2 for the limestone necessary to make 1 ton of burnt lime.

Burning.

The most suitable kiln would probably be a continuous shaft kiln using wood fuel in external grates. Some coal might be used and there is the possibility of a deficiency of wood. Firewood can be delivered at Voblapur at Rs. 6 per ton, but we will allow Rs. 7 to give a wider range. The quantity of wood required is not known exactly, but probably $\frac{1}{2}$ a ton would suffice per ton of burnt lime. The railway is about 12 miles from Voblapur and a light feeder line would be required on which the cost of transport and loading should not exceed Re. 1.

We may roughly estimate the cost of the lime delivered on the railway as follows :—

TABLE 30—*Estimate of cost of burnt lime from limestone.*

	Rs.	a.	p.
2 tons limestone at kilns	2	0	0
½ ton firewood	3	8	0
Labour and upkeep of kiln	2	0	0
Transport and loading on railway ...	1	0	0
Total per ton of lime (f. o. r.) ...	8	8	0

In some cases bagging may be necessary and this would be extra.

Comparing this with the cost of Rs. 14 for kankar lime at Bangalore or Kannambadi it should be possible to deliver the lime at those places for less than what the kankar lime costs and for much less when the relative proportions of lime (CaO) are taken into account. That burnt from kankar will probably average not more than 65% of lime while that from the limestone will average about 86% including magnesia. One ton of the latter should therefore be worth 1⅓ tons of the former if equally suitable in other respects. Lime sells in Bangalore for about Rs. 18 per ton and 1⅓ tons will cost Rs. 24 and the difference between this figure and the Rs. 8-8-0 obtained above should leave a fair margin of profit after paying for supervision, taxes, transport and sale. Whether the figures given prove to be very accurate or not the project appears to be worth serious investigation. The fact that the lime is brown will preclude its use for several purposes, but for ordinary building purposes, preparation of surki mortar, etc., there should be a considerable demand amounting to several thousand tons a year. For the second stage of the Kannambadi dam some 48,000 tons of kankar will be required and it will probably be more difficult and expensive to supply this

from kankar obtainable in the neighbourhood than is the case at present when the lime costs about Rs. 14 per ton as shown above under the head of "Kankar."

Hydrated lime.

Hydrated lime is lime which has been carefully slaked and sieved at the works and does not require further slaking by the consumer but merely mixing with water. It has the advantage that it can be stored for a considerable time without much deterioration and that the erratic and uncertain slaking usually performed at the building site is avoided.

Lime for paper pulp.

The manufacture of paper pulp at Shimoga is under investigation and if it is undertaken there will be a steady demand for some 3,000 tons of burnt lime per annum. This would give additional work and reduce standing charges.

Cement.

In considering further outlets for the products of the limestone quarries we may briefly refer to the production of cements. We have not found a natural-cement rock near Voblapur. Some of the siliceous limestones from the Tarikere area might produce a natural cement—though we are doubtful about it—but that would be of no use for a works at Voblapur where the object should be to concentrate as much quarrying, burning and crushing work as possible in order to secure a sufficient total volume of business to bring the standing charges down to within reasonable limits. There is not enough demand in Mysore in any one line to justify the erection of an economical plant and the employment of high class supervision, labour and machinery and hence the need for endeavouring to concentrate several lines of work in one place. For this reason it would probably be impossible to run a commercially successful plant for making natural cement near Tarikere even if the rock is found to be suitable and as already stated we do not know at present of any likely rock near Voblapur.

As regards Portland Cement no doubt the high calcium limestones of Voblapur could be used and some experiments

might be made with the dolomites though, for reasons with which we are not acquainted, the presence of more than 3 or 4 per cent of MgO is invariably barred in a Portland Cement specification. In addition to the limestone a suitable clay or shale is required and the presence of a suitable supply has not been investigated yet. As this Bulletin is meant to be suggestive we may briefly consider the possibilities, but we hesitate to say much about such a technical and highly specialized process as the production of a high class Portland Cement. The consumption in Mysore is small. We have not got figures but probably it does not exceed a few hundred tons a year and there is little chance for export. No doubt its use will increase and we may make a rough estimate for an output of 5,000 a year for the sake of argument.

TABLE 31—*Estimate of cost of Portland Cement.*

	Rs.	a.	p.
1¼ tons limestone at Re. 1	1	4	0
½ ton dry clay at Rs. 1-8-0 (?)	0	8	0
Power for grinding raw materials and clinker, using coal at Rs. 22 per ton	12	0	0
Powdered coal for rotary kiln	8	0	0
Labour	2	8	0
Supplies, repairs, etc.	4	0	0
Supervision, laboratory, office, etc. ...	3	8	0
Depreciation 10% on 2½ lakhs	5	0	0
Interest 5%	2	8	0
Cost of bags or barrels	5	0	0
Total per ton packed ...	44	4	0

Imported cement costs about Rs. 10 per barrel or, say, Rs. 60 per ton in Bangalore and even assuming that the quality of the Mysore cement compared well with that of the imported article there is little margin for transport, sales and profit. At present the consumption is only a fraction of 5,000 tons a year and for such smaller amount the costs per ton

would go up considerably. On the other hand if the demand goes up to any thing like the 5,000 tons on which the estimate has been based there are various reductions which might be suggested. The most important of these is in the power required for grinding, etc., for which electricity might be substituted for coal. If electric power could be supplied at 0·5 anna per unit the cost of power should come down to half or less, a saving of 6 or 7 rupees per ton, and if the work is done in conjunction with burning and crushing of limestone for other purposes the charges for staff, depreciation, etc., could be partly allotted to this other work making a further reduction of a few rupees per ton. We might thus expect to reduce costs to Rs. 34 or 35 per ton as compared with Rs. 60 for the imported article and if the cement was good enough to sell at Rs. 50 to 60, profitable work should be possible. Cement making is a delicate and tricky operation, but we have shown reasonable grounds for a further investigation by experts.

Limestone for flux.

In connection with the iron smelting scheme previously referred to there would be a demand for some 5,000 tons of limestone per annum. For this purpose low silica is most essential and as the presence of magnesia is not a serious detriment some of the dolomite from Voblapur could be used, as it is much lower in silica than the limestone. It should be possible to deliver the rock at Shimoga for about Rs. 5 per ton if low freights are obtained, say $\frac{1}{8}$th or $\frac{1}{10}$th of a pie per maund per mile.

Crushed limestone.

Many of the soils of Mysore are deficient in lime and it is worth while considering whether the lime needed to make good this deficiency can be supplied at a sufficiently low price to prove attractive. Dr. Coleman, Director of Agriculture, has furnished us with information as to what has been done in this direction elsewhere and has undertaken to have experimental tests made with both limestone and dolomite, both burnt and finely ground, and for this purpose about 20 tons of rock have been obtained and suitably prepared. There is still much difference of opinion

as to the relative values of burnt lime and ground limestone and also as to the effect of the presence of magnesia, but there is a considerable amount of experimental evidence tending to show that magnesia is not detrimental and may replace an equivalent quantity of lime and further that the raw ground limestone is as useful as burnt lime though slower in action. A greater weight of the limestone must be used to furnish the same quantity of lime—roughly about twice as much—and it is still uncertain whether these proportions will afford equivalent results. It does not appear necessary for the limestone to be very finely ground and it is probably sufficient for it to pass through a 12 or 14 mesh in which case much of the product will be very much finer. The finer portion will be acted upon comparatively quickly by the acids in the soil and the coarser portions will come into use in the course of a few years. Assuming that the crushed limestone proves successful and that 2 tons are required per acre every five years we may consider the probable demand. Many of the coffee estates require lime and some have purchased burnt lime at a cost of Rs. 30 per ton at Birur. If the lime was cheaper much more would be used. There are 100,000 acres of coffee and if owners of one-fourth of the area were prepared to pay for lime at the rate of 2 tons of limestone per acre every five years we should have a demand for 10,000 tons of crushed limestone per year. The demand would probably tend to increase, and there might be a considerable demand in the case of other high class crops also, so that we might expect a demand of 10,000 tons and upwards for crushed limestone which would be a considerable addition to the lime business and help to reduce standing charges in quarrying, crushing, working of tramway, etc. If we allow Re. 1 for quarrying, Rs. 2 for crushing and Rs. 2 for transport the cost at Birur would be Rs. 5 per ton and its value should be several rupees more which would cover other charges, profit, etc. It seems probable that 2 tons of the crushed limestone would be cheaper than 1 ton of burnt lime and considerably cheaper than any form of lime at present obtainable.

CONCLUSION.

We have shown that large quantities of fairly good limestone and dolomite occur in the neighbourhood of Voblapur in the Tumkur District not far from the railway.

Hitherto no limestone has been used in the State and we have suggested various lines and schemes which if successful would create a demand for some 20,000 or more tons of limestone per annum and this with the necessary burning, crushing and other treatment suggests the possibility of an industry on a sufficient scale to pay for the employment of the necessary supervision and plant on up-to-date lines and to yield a fair margin of profit. The proposition appears, at any rate, to warrant expert technical investigation.

CLAYS.

Clays may be described as earthy materials which become plastic when wetted. They are formed by the alteration or decomposition of rocks and consist of the residual products of such decomposition. They are called *residual* clays when they remain *in situ* on or in the rocks from which they have been formed and *transported* clays when formed by the denudation and removal of these decomposition products by water and their subsequent deposition in sedimentary or alluvial layers. In some cases the deposits may be wind borne.

The base of most clays consists of hydrous silicates of alumina of which the most important is the mineral kaolinite. The character of the clay depends on the proportion of other ingredients or impurities such as sand, various silicates and oxide of iron. There are few, if any, noteworthy deposits of clay in Mysore, but common clays suitable for the manufacture of bricks and sometimes tiles are widely distributed in the flood plains along the river courses and in the numerous tank beds situated along shallow valleys. These deposits are usually very mixed, layers of plastic clay alternating with layers of sand and loam, and extensive beds of high grade plastic clay are rare.

Ordinary bricks can be made almost anywhere and the class of product obtained is largely a question of the selection and treatment of the clay and the care taken in moulding and burning. In most places cheapness is the great consideration rather than finish or durability and it is doubtful if the majority of bricks now made are as good as those made in former years and certainly not as good as the old hand-made bricks to be found in old forts and buildings.

Ordinary hand-made bricks, sun-dried, are sold for Rs. 1-8-0 to Rs. 2 per thousand. If burnt, they cost from Rs. 4-8-0 to Rs. 5 per thousand.

Very good pressed bricks can be made at about Rs. 10 per thousand and the development of this class of work might be encouraged. The difficulty is to persuade people to pay the extra price for the more durable article when the common burnt brick is available and serves the purpose sufficiently well for the time. There is a demand for higher class bricks in the larger towns and wire cut bricks are supplied by the Bangalore City Brick & Tile Works for about Rs. 18 per thousand. Clays suitable for tiles are found in many places and are used by local workers for the production of flat and pot tiles, chatties, etc. In recent years there has been an increasing demand for tiles of the "Mangalore" pattern which require a good deal more skill and plant for their manufacture and in which a large and steady output would appear to be one of the chief factors for success. Works for making this class of tile have been put up at Bangalore, Mysore, Saklespur, Harrihalli, Sringeri and Sagar, but with the exception of the first they do not appear to have met with much success and are reported to require remodelling on more modern lines. A new factory is stated to be in course of erection at Tirthahalli in which the kilns and plant will be of an up-to-date type and if commercially successful others may follow.

KAOLIN.

Kaolin or China-clay is a name applied to white-burning,

slightly plastic, clays of a very finely pulverulent texture, which are generally considered to be largely composed of the mineral Kaolinite—a hydrous silicate of alumina.

It is most usually derived from the decomposition of the felspars of granites and pegmatites and is found as part of the decomposed rock mass in admixture with quartz, mica and other silicates which have not been decomposed or removed. For this reason, it is necessary to wash the decomposed mass so as to separate the very fine kaolin from the coarser mineral grains and the term kaolin is usually restricted to the fine white clay so prepared. More rarely white clays and lithomarges are found in beds or masses in a sufficiently fine or pure state to be dug out and used for pottery work and these are sometimes included in the term kaolin. The decomposition of the felspars and the production of kaolin is a wide-spread result of weathering in which water and carbonic acid play the most important parts. In order that a deposit of kaolinized material should be formed, it is necessary not only that the rock should be very highly decomposed but that the soft decomposed material should be protected from denudation. In Mysore we have cases of highly decomposed pegmatite veins containing kaolin and protected from denudation by the harder enclosing gneiss or granite and there are many cases of such veins or of white bands of the granite or gneiss which are highly decomposed and protected by an overlying layer of laterite or hard laterite soil.

The depth to which the kaolinized material may be expected to extend is determined by the depth of extreme decomposition and will average to some 30 to 50 feet from surface. Below this point the rock begins to get harder and much of the felspar is undecomposed so that the amount of kaolin obtainable on washing will diminish rapidly and the resulting product will probably be less fine and soft.

In the great kaolin areas of Cornwall in England the conditions are very different. There, large masses of white decomposed granite are found in which intense decomposition

extends downwards for some hundreds of feet with the production of exceptionally fine white kaolin throughout the mass. These decomposed masses are often of considerable lateral extent and individual pits have an area of many acres. Many authorities consider that kaolinization in Cornwall is due to the action of deep seated igneous vapours and is not due primarily to mere surface weathering so that in mode of origin as well as in extent and purity the kaolin deposits of Cornwall are very different from those of Mysore.

Distribution.

Kaolinized granite and gneiss occurs abundantly in several parts of Mysore beneath the laterite caps and the stiff laterite soils derived from them or from various more or less lateritic materials. These masses are very variable in colour and are usually yellow, pink or red and it is only rarely that bands or veins are found which are sufficiently white to yield anything which could be classed as kaolin. The whiter bands and veins so far discovered are of small lateral extent and from what has already been said they cannot have any considerable extension in depth. Some of these might yield from a few hundred to a few thousand tons of kaolin, but none of them would appear to be sufficiently extensive to justify the erection of an up-to-date washing plant or the provision of any special transport facilities to a railway, and in most cases they are far removed from existing lines.

Samples of kaolin have been obtained from the following localities and remarks are added as to their characters.

Mysore District.—On the Melkote hill there are two or three small deposits of decomposed gneiss from which sticks of kaolin are prepared for making caste-marks. The material contains from 10½ to 14 per cent of levigated kaolin which is fairly white, but burns buff colour.

Bangalore District.—At Gollhalli the decomposed gneiss in a nulla contains some decomposed pegmatite veins from which 25 to 30 per cent of white kaolin can be obtained which burns white. The quality is said to be good, but the quantity is not large—probably inside of 1,000 tons. Outcropping veins

are contaminated with iron, but a good vein, a few feet thick, was found at a depth of 15 feet. Mining of any considerable quantity would be difficult owing to the tendency for pits and shafts to close up during the rains.

Near Hindiganal in the Hoskote Taluk kaolin occurs in decomposed gneiss beneath the laterite. Most of it is slightly yellow or pink and is not favourably reported on.

Kadur District.—Samples of fairly white kaolin have been obtained from a number of places, but on further examination the quantities available were found to be too small to be worth further attention. In the following three places somewhat larger quantities occur:—

At Asgod in the Koppa Taluk there is a considerable quantity of decomposed gneiss beneath a few feet of soil from which possibly a couple of thousand tons of kaolin could be extracted. The colour is however distinctly yellowish and this will probably debar its use for most purposes.

At Kokkod in the same taluk a deposit has been found which yields about 22 per cent of white kaolin. The quality seems fairly good and if wanted it is probable that one or two thousand tons might be obtained and possibly more in the neighbourhood.

At Kikri in the Sringeri Jaghir a pegmatite vein, about 12 feet wide and a furlong or more in length, yielded some 23 per cent of white kaolin which however contains a good deal of fine mica which is difficult to separate by levigation in tubs. Probably one or two thousand tons could be obtained.

Chitaldrug District.—Some occurrences of greyish white to purple materials have been noted near Bhimasandra and Marikanave, which might be classed as lithomarge, and would probably not be valued as kaolin on account of bad colour.

It will be seen that in no case has anything of the nature of a large deposit been found which would justify the erection of a modern plant or one in which working expenses

would be low. Several tons of material have been excavated departmentally and levigated in tubs and a number of bags of prepared kaolin. have been sent to Bombay to ascertain values.

A large amount of English kaolin is used in Bombay for cotton sizing and is valued at some Rs. 50 per ton in normal times. Local supplies of kaolin are now being sold in Bombay at this figure, or over, owing to war freights, but it is reported that they found a market with difficulty before the war.

Under these circumstances, it is doubtful if supplies could be sent from Mysore to Bombay at a profit in view of their distance from a railway and the long railway lead to Bombay. Enquiries are being made on these points.

Some time ago it was suggested that a porcelain factory should be started in the State and doubtless our small deposits of kaolin would prove useful for some classes of porcelain or pottery ware. It must be remembered however that for the manufacture of such wares many other ingredients are required besides kaolin and Mr. Fern of the School of Arts, Bombay, has reported that it would not be possible to manufacture white earthenware or soft paste porcelain owing to the absence of plastic or ball clays which burn white. He states that hard paste porcelain might be made but that highly skilled labour is required. A valuable account of the occurrence, mining and preparation of Kaolin will be found in "A handbook to the collection of kaolin, China clay and China stone in the Museum of Practical Geology, Jermyn St., London, S. W." by J. Allen Howe, B.Sc.., F.G.S.

FELSPAR.

Felspar is used in the pottery industry for the manufacture of certain varieties of porcelain and for the preparation of glazes. So far there has been no demand for it in Mysore but, if required, it could be obtained in many places from the coarser grained pegmatites in which the crystals are sufficiently large to permit of being hand picked from the associated

quartz. Both white and pink felspars occur, most of which are soda felspars, but some potash felspars (orthoclase and microcline) have also been noted. Little attention has been paid to the mineral owing to the absence of any demand for it.

A number of samples have been collected from time to time and some from the mica pits near Vadesamudra have been reported to be suitable for glazes and other pottery purposes.

BUILDING AND ORNAMENTAL STONES.

Many parts of the State are well supplied with building stones which can be obtained from the surface exposures of granite and gneiss many of which are remarkably fresh.

The gneiss, some of which is highly streaked or banded and some of which is a fine uniform grey granite, is usually quarried by fire-splitting, whereby successive layers of a few inches in thickness are separated from the mass below by the action of a fire built on the surface and slowly moved across it.

The loosened layers are split into slabs 2 feet wide and 10 to 15 feet long by wedging. The slabs may run up to 6 or 8 inches in thickness and thicker blocks are obtained by the blasting and wedging of thicker layers separated by natural joint planes.

A number of red granites or grey granites with reddish felspars occur in several places and are used locally. Amongst these may be mentioned the granites of the Closepet range, the Arsikere and Banavar massifs and that of Chamundi.

The potstones of the Hassan and Mysore Districts have been largely used in old temples especially where intricate carving is required.

The Turuvekere trap, a dark and rather soft amphibolite passing in places into potstone, has been used in several cases for ornamental work and takes a fine black polish.

A varied series of porphyry and felsite dykes occur in the Seringapatam, Mandya and Mysore taluks of which a number have been used as ornamental stones in the new Palace at Mysore.

A green quartzite or gneiss containing the chromium mica *fuchsite* occurs in several places and has been used sometimes for inlaid work. The best variety comes from Belvadi in the Kadur District.

The more ornamental stones are, however, rarely used owing to their greater cost and difficulty of extraction in comparison with the commoner forms of grey granite and gneiss. Suggestions have been put forward from time to time for the quarrying and dressing of some of these with a view to export, but no practical scheme of a profitable aspect has yet been put forward.

A description of many of the porphyry and felsite dykes will be found in the Appendix to Vol. VII of the Records of the Department and a large variety of polished samples of the principal building stones of the State can be seen in the museum of the Department of Mines and Geology, Bangalore, and information obtained as to their location, mode of occurrence, etc.

IV. Rare Minerals.

A few minerals containing some of the rarer elements have been found in Mysore and though they are too scarce to be of economic importance they may be referred to briefly, in view of the fact that they are often the subject of attention and enquiry.

Monazite.

Monazite occurs sparingly in crystals or grains in certain gneisses and pegmatites. The mineral is yellow to red in colour and is essentially a phosphate containing cerium and thorium and other rare metals. Its value depends chiefly on the amount of thorium present, the oxide of which is used in the preparation of incandescent gas mantles.

In the sands derived from these rocks it may become more abundant and where these sands are subjected to the sorting action of waves on the sea-shore the degree of concentration may become considerable and valuable deposits may be formed, such as those discovered in recent years on the Travancore coast.

In Mysore, there has been little concentration and no deposits of any value have been found.

A few handfuls of monazite crystals have been obtained from decomposed pegmatite near the 5th mile on the Bangalore-Kankanhalli road. The quantity available is small and the amount of thoria in the mineral is only some 2½% which compares very unfavourably with the monazite from Travancore, which is reported to contain from 6 to 10%.

On the west side of Kolar schists—near the Bowringpet Road—Mr. Louis Stromeyer found a number of pieces of a quartzose gneiss containing specks of a reddish mineral which

on being tested proved to be monazite or some allied mineral. No notable quantity of either the rock or mineral has however been located.

Some licenses have been taken out in the Kadur and Hassan Districts and a large number of washings made of the stream sands some of which were stated to contain thorium. No analyses have been furnished, but a large number of the concentrates from the sands, which were examined, failed to show any appreciable quantity of monazite.

A large number of river washings have been made from time to time by officers of the Department—chiefly in the neighbourhood of the charnockites of the Mysore District—and occasionally a few grains of monazite have been detected, but nothing of any particular value.

Samarskite.

A number of small pieces and plates of what appears to be Samarskite were found associated with the monazite in the decomposed pegmatite near Bangalore.

Columbite.

Crystals and lumps of columbite are sometimes found in the pegmatites of Mysore especially in the mica pits. The mineral is nearly black with sub-metallic lustre and is composed of niobate and tantalate of iron and manganese.

Several hundred pounds were collected by licensees from pits near Yelwal and Tagadur in the Mysore District and reported as tantalite. The distinction between tantalite and columbite depends on the proportion of tantalic acid present and a sample from Tagadur was found to contain only 1·14%. It therefore belongs to the variety columbite and is of no value.

Beryl.

Crystals of pale-green beryl have been found in a quartz vein near the Kempambudi Tank, Bangalore, and some crystals of a yellowish colour in a cutting on the road leading to Melkote in a pegmatite. In both cases the mineral is much fissured and poor in colour and has no value as a gem stone.

Graphite.

Graphite, one of the crystallised forms of carbon, though not a rare mineral, may be included here as it occurs only in very limited quantities. It has been found in several places but nowhere in sufficient abundance to be of commercial value. It occurs occasionally in gneiss and particularly in some of the gneisses of the Mysore District. Near Bangalore it has been found as micaceous looking spangles in a white quartzite or fine grained quartz vein in gneiss. A concentration test of this showed about ½% of graphite in the rock. It occurs associated with some of the auriferous quartz of the Kolar Field in some workings from Trial shaft, Nundydrug, on what is supposed to be a continuation of the Oriental Lode. In this case the selvage edges of the vein and some of the joints or cracks along which movement has taken place are freely coated with graphite. To the north of the Kolar Field some fine grained graphite schist occurs near the old working at Manighatta and somewhat similar material has been found in the Chitaldrug schists and amongst the chloritic and hornblendic schists on the scarp of the Bababudans near Hoskan. In the last instance, the schists appears to consist of fine grained chlorite or talc with finely divided quartz and iron ore, the whole being penetrated by short lenses and veins of white quartz on the edges of which the graphite is somewhat concentrated. As the schist was quite black and marked paper readily, an attempt was made to separate the graphite which is in the form of very fine dust or particles. By levigation an impalpable powder was obtained containing practically all the graphite which was present to the extent of 6½%. The amount of graphite in the rock as a whole would be about 3%. The levigated powder is so fine that it would probably be impossible to further concentrate the graphite from it and the powder itself does not appear to be of any use or value except possibly as a dark pigment.

Bangalore,

29th May 1916.

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DEPARTMENT OF MINES & GEOLOGY

MYSORE STATE

LIST OF PUBLICATIONS

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VOL. I, 1894 TO 1897.

Part 1.—General Report from 1st October 1894 to 31st December 1895. Preliminary report on the Iron Ores in the neighbourhood of Malvalli. Notes on the Corundum deposits in the south of Mysore. Notes on prospecting work for minerals in Kadur and Mysore Districts. Notes on the Marikanave Gorge.

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Part 3.—Annual Report for 1897. Notes on the Mysore Decorative and Building stones. The porphyry dykes in Seringapatam, T.-Narsipur and Mandya Taluks. Note on Ruby Corundum from Sringeri. Report of Prospecting work in 1897. Notes on the Honnegudda and Hiriyur Mining blocks, Shimoga District. Report on the Geology of the Kotemaradi block, Chitaldrug District. Notes on the Ajjampur Mining Block, Kadur District. Report of the Chief Inspector of Mines in Mysore for 1897.

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Appendix—Note on the geology of the Kolar Schists and surrounding rocks.
Map of the Kolar Schist Belt—Plate I.
Map of the Kolar Gold Field—Plate II.

Year 1900.—Labour, wages and costs. Cauvery Falls Power Scheme.

Year 1901.—Water-supply for the Kolar Field. Report on the Woolagiri and Amble Mining Blocks, Mysore District, with map and sections. Report on the Ajjampur Block, Kadur District, with map and sections. Note on the New Town (Robertsonpet), Kolar Gold Field, by F. E. C. Carr, Esq., Deputy Commissioner.

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Mine Signalling with diagrams.
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